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Journal

of

THE ROYAL AERONAUTICAL SOCIETY

JUNE 1956

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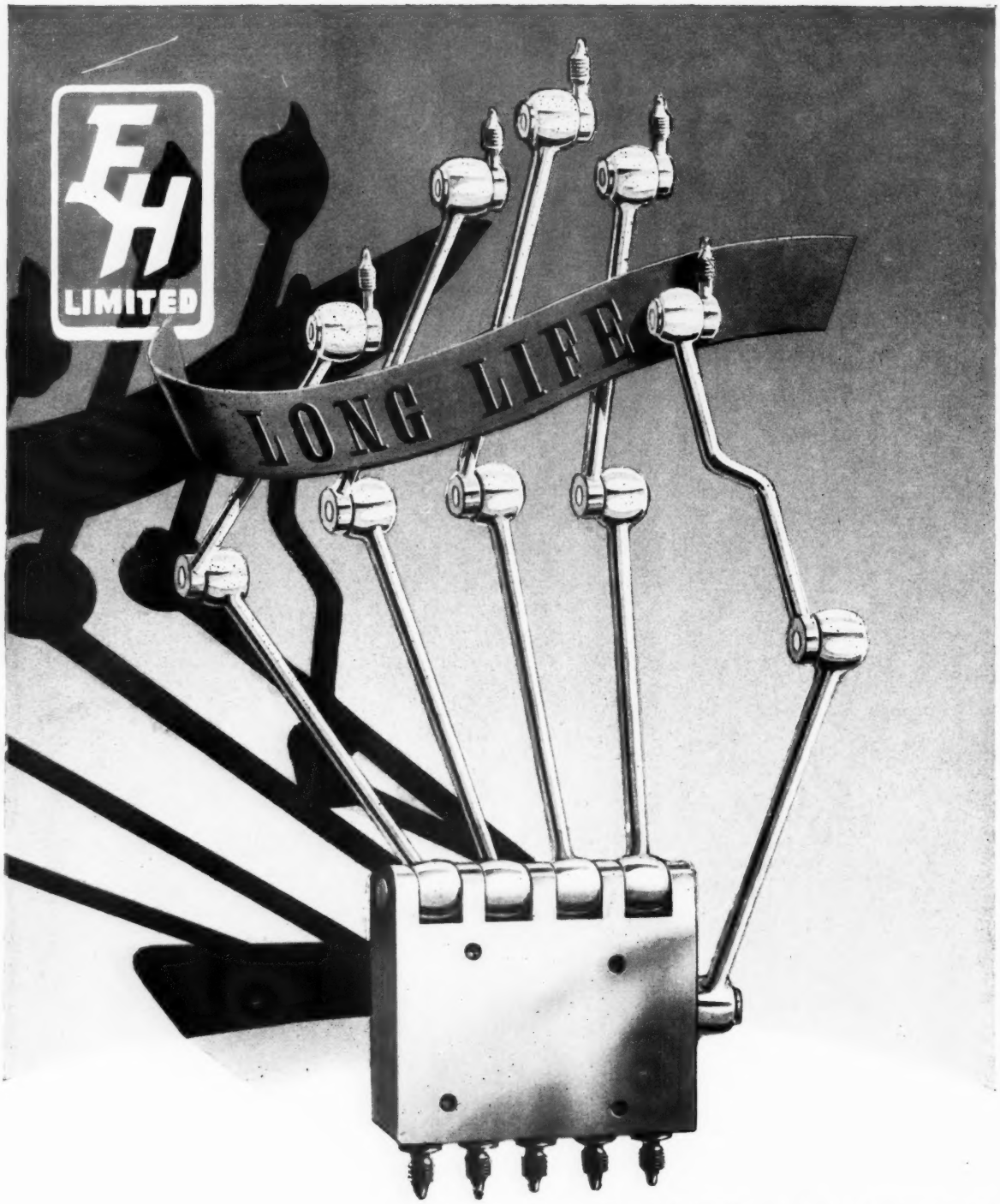

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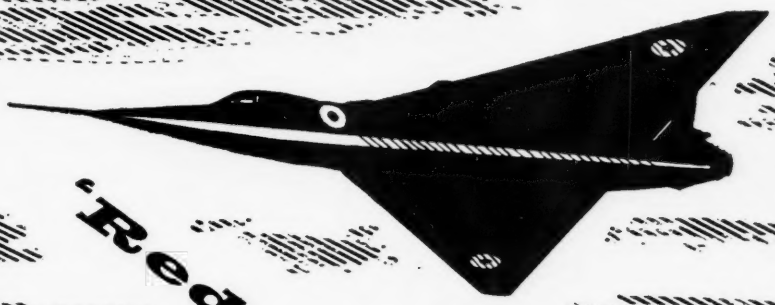

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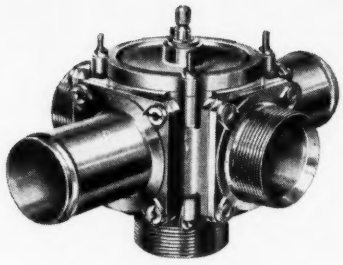

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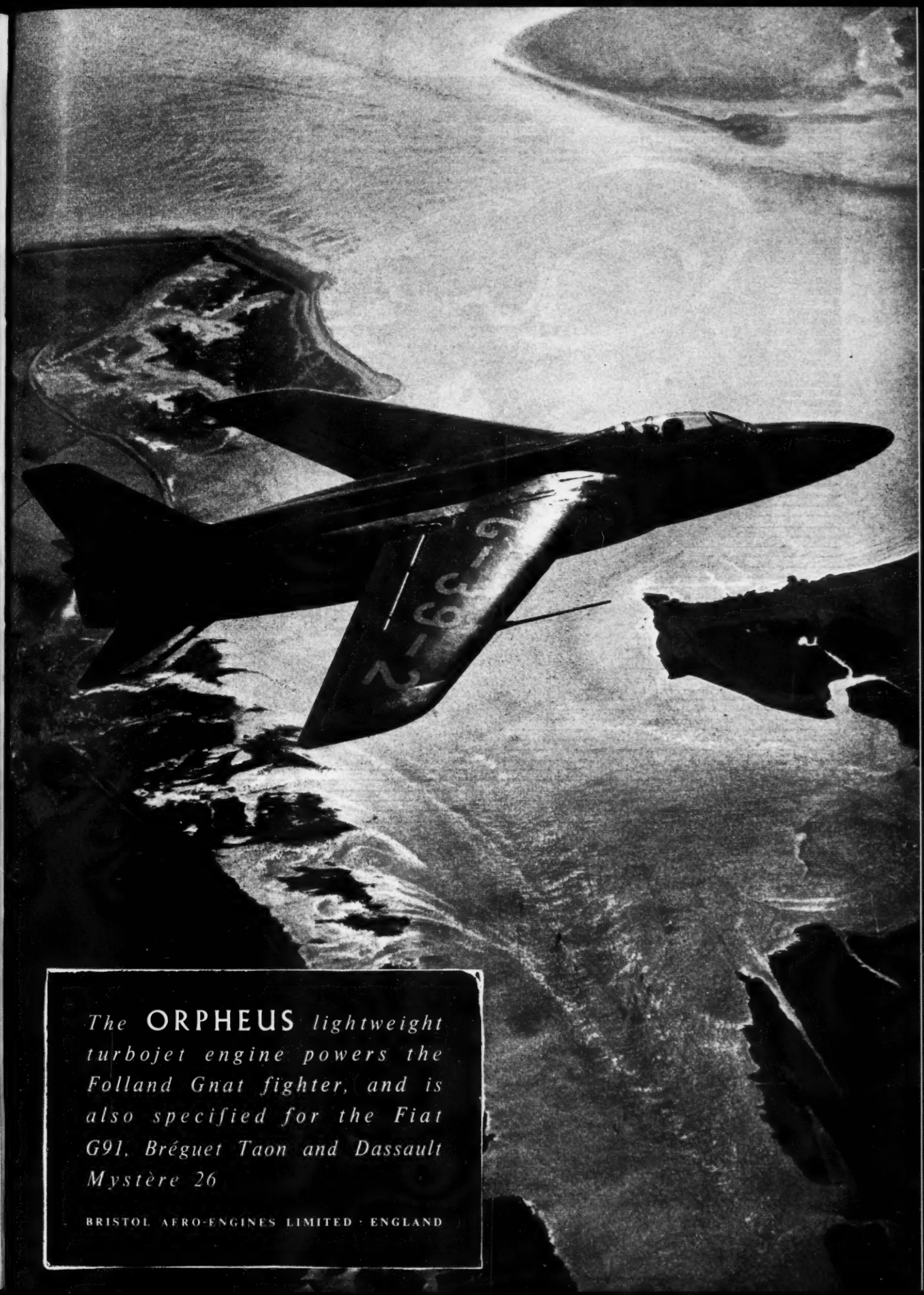

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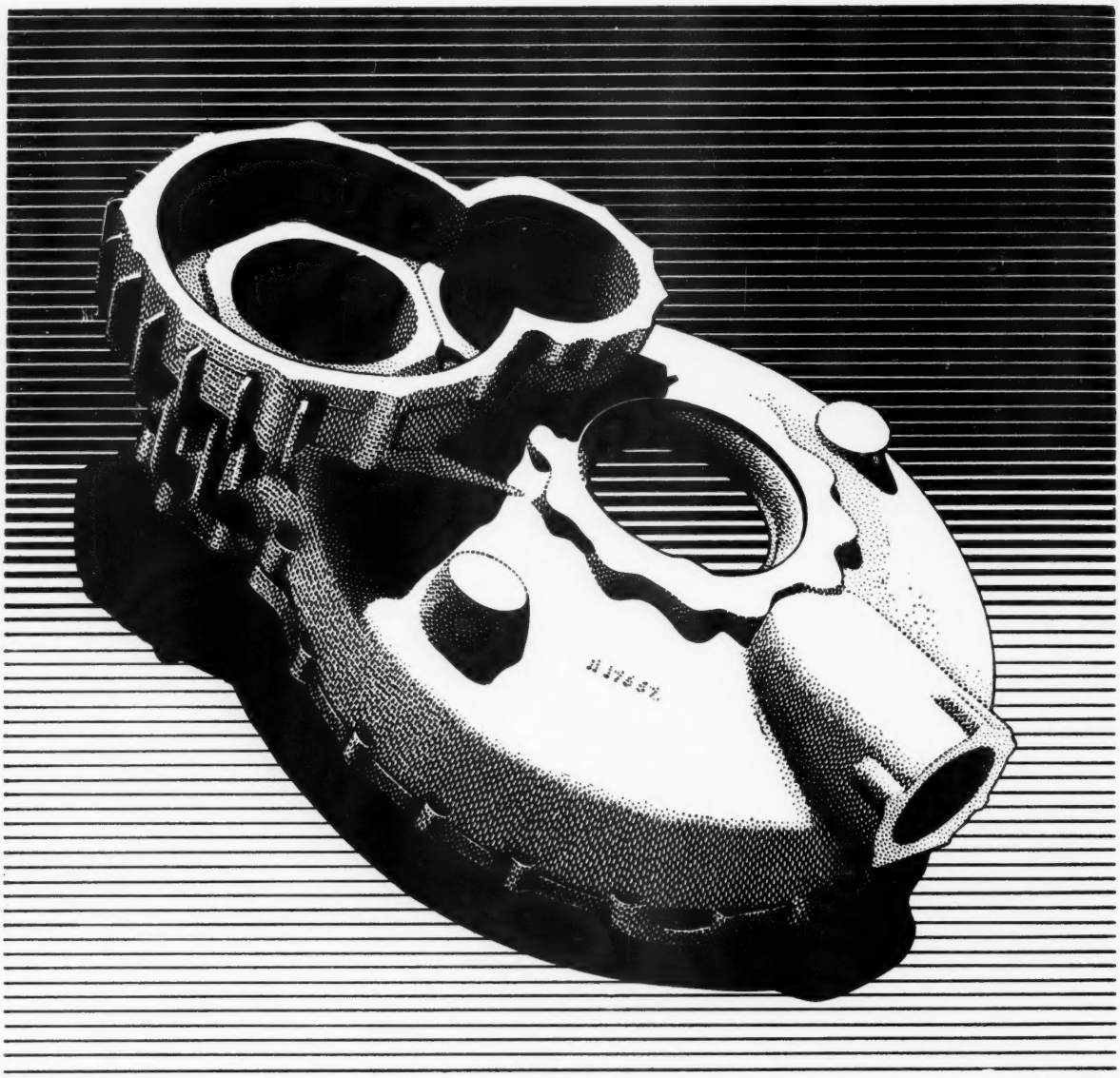

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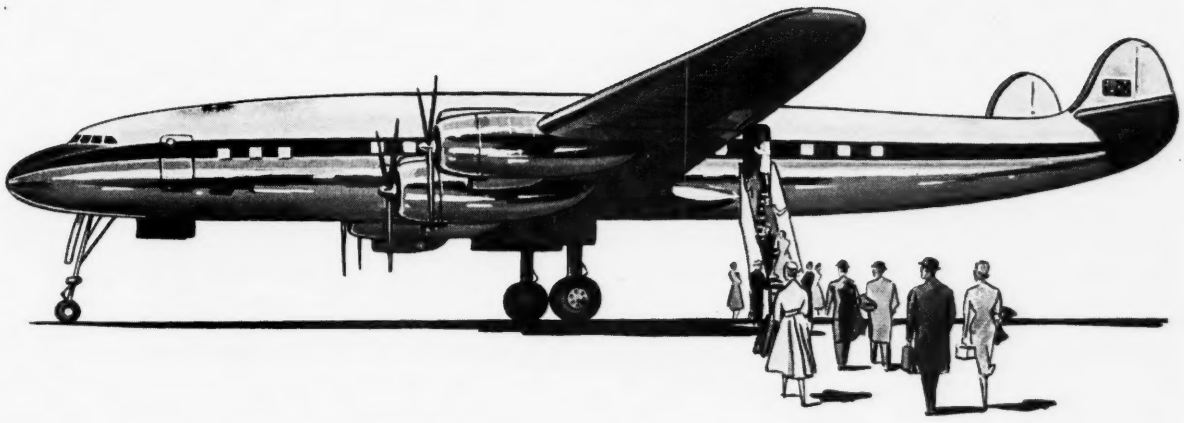

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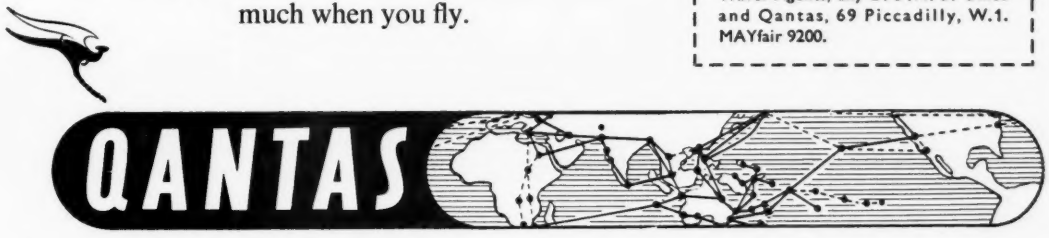

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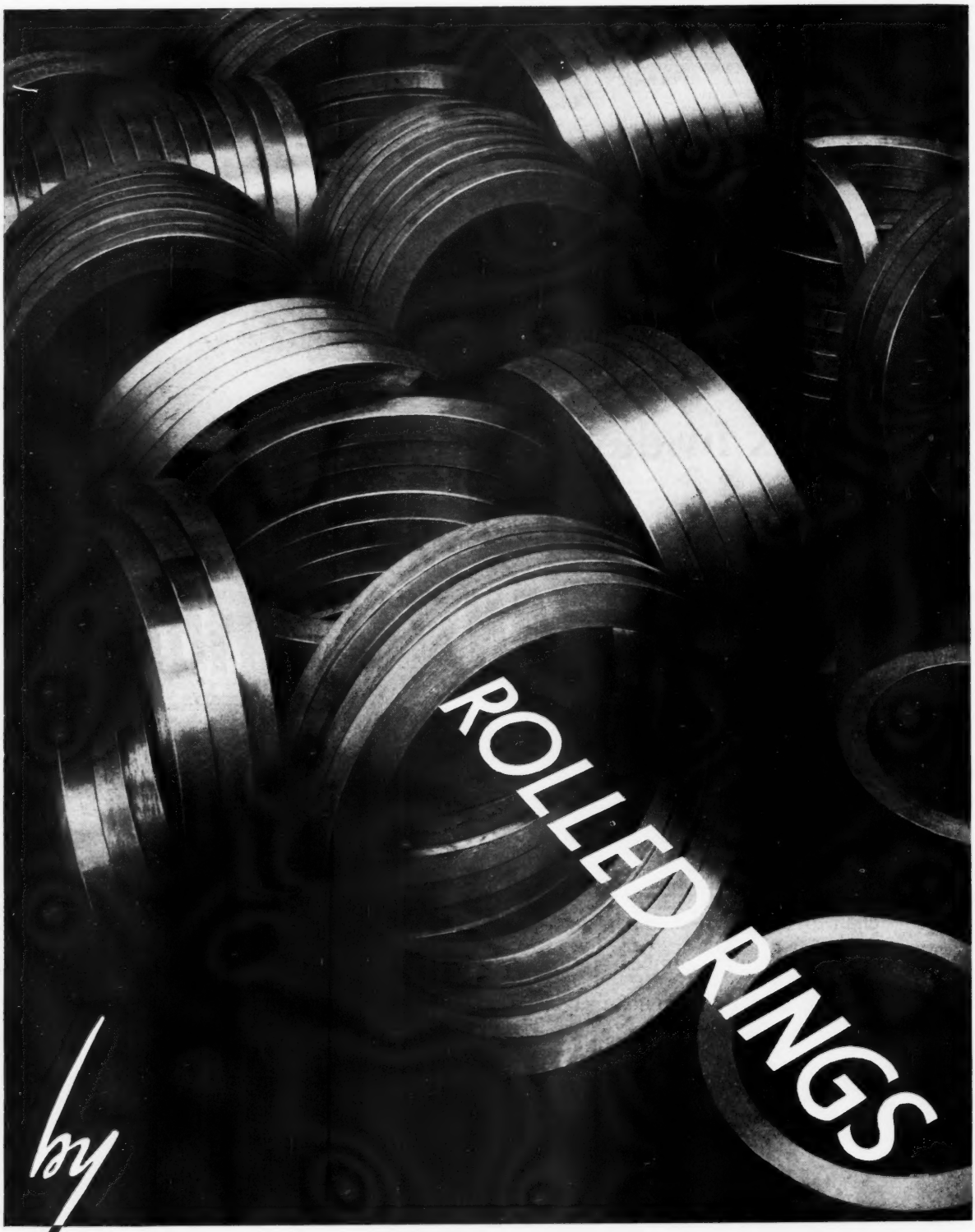
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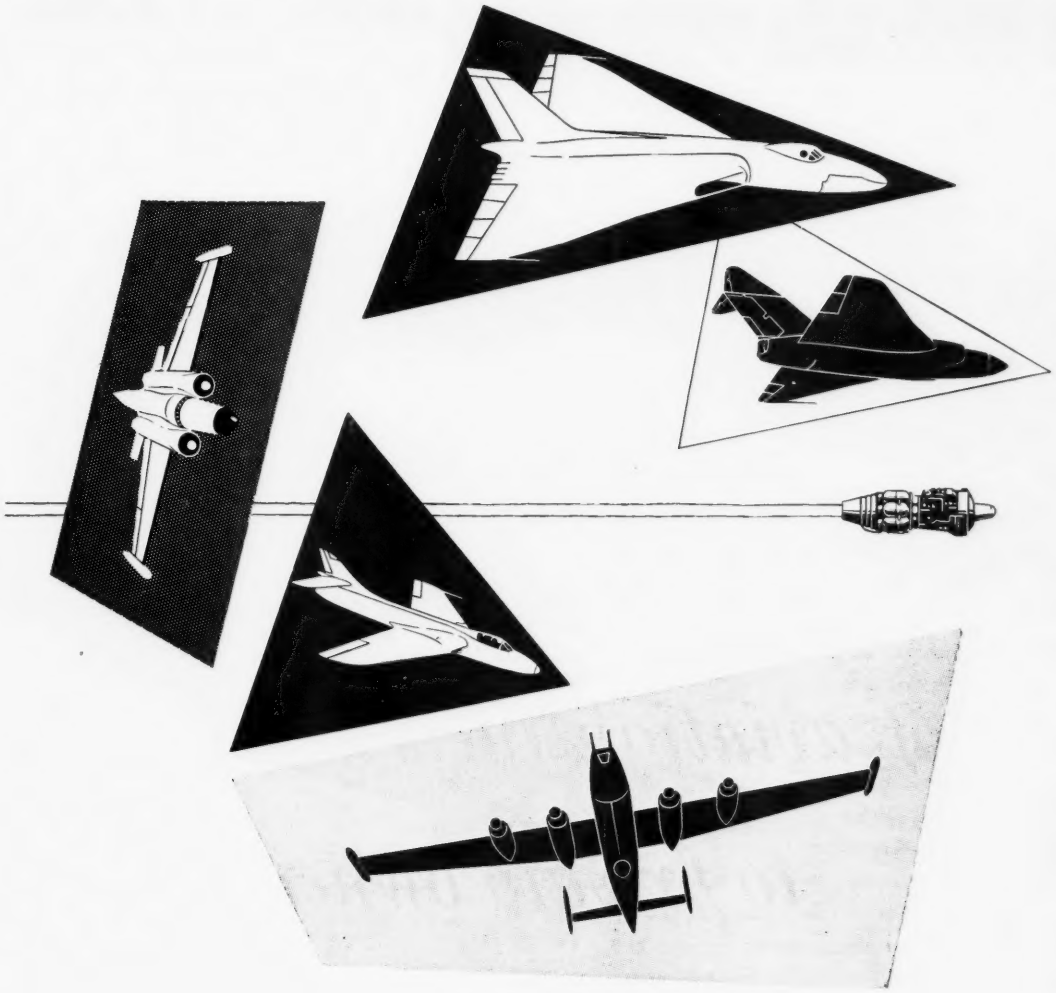

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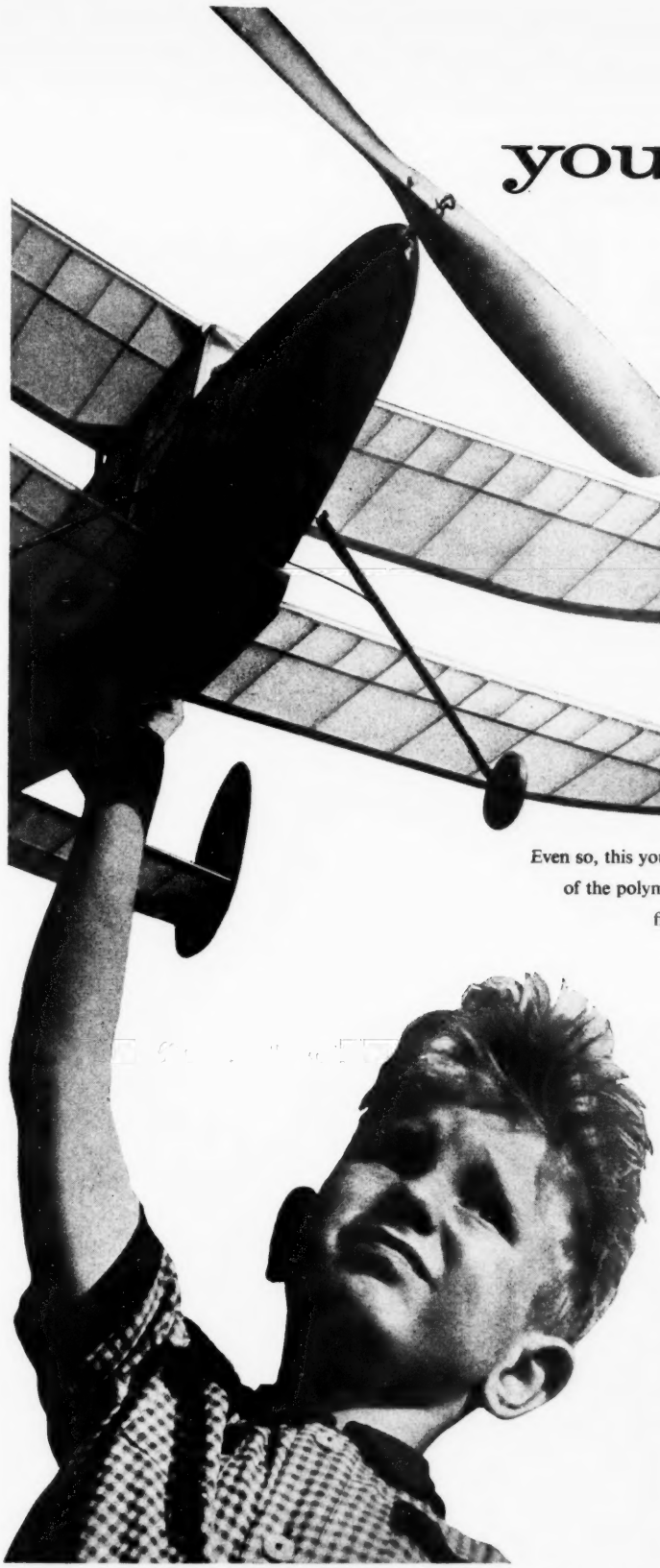

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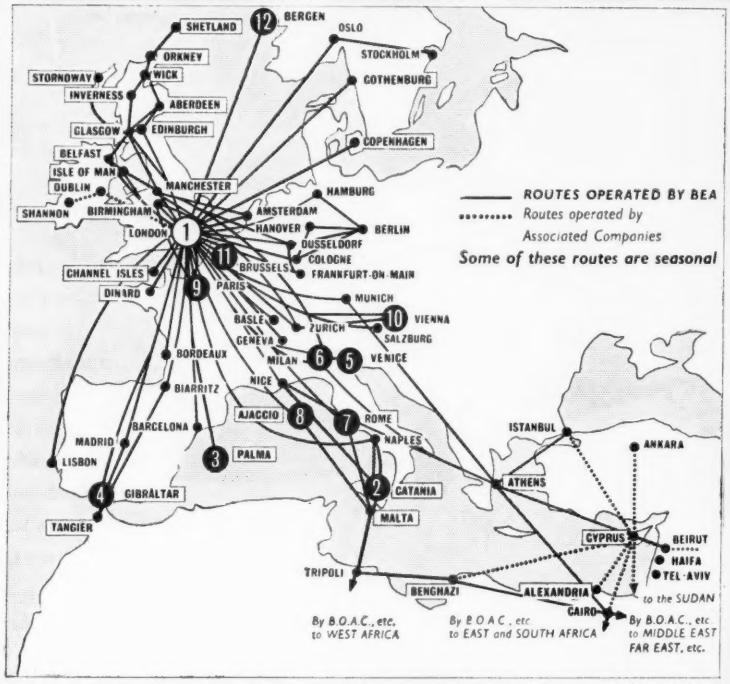

1. *Sir Walter Raleigh (1552-1618) pioneer of the English colonies.*
2. *Garibaldi leading his "Thousand" in Sicily, 1859.*
3. *Chopin and George Sand who went to Majorca in 1838.*
4. *The English fleet under Admiral Rooke capturing Gibraltar, 1704.*
5. *Marco Polo (1254-1324), Venetian explorer, on his way back from China.*
6. *Frederick Barbarossa, German Emperor, entering Milan, 1162.*
7. *The Roman Emperor Caligula (A.D. 37-41), who declared his horse Incitatus a priest and a consul.*
8. *Napoleon, born in Corsica in 1769, on board H.M.S. Bellerophon after his defeat at Waterloo.*
9. *The French Revolution, 1789. Storming of the Bastille.*
10. *Johann Strauss (1825-1899), Viennese composer of the "Blue Danube" and many other waltzes.*
11. *The Duke of Wellington at the Battle of Waterloo (1815).*
12. *Amundsen, Norwegian explorer, on his way to the South Pole (1911).*

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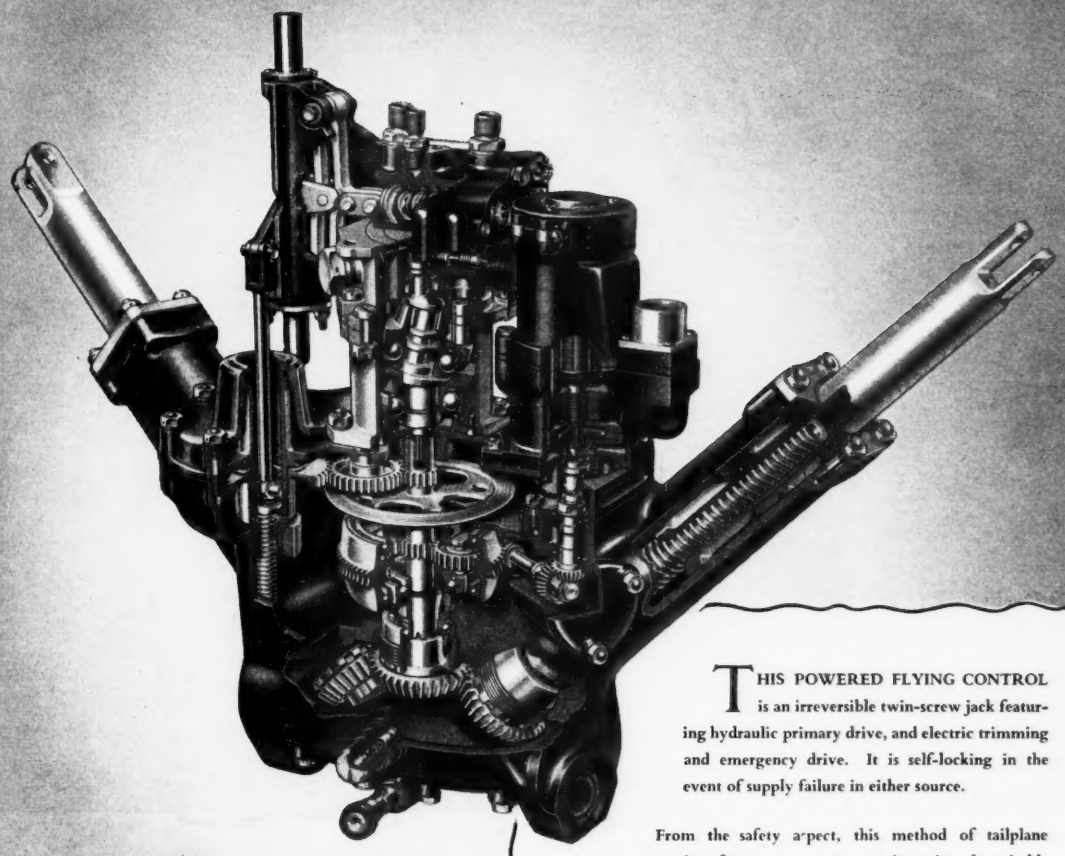

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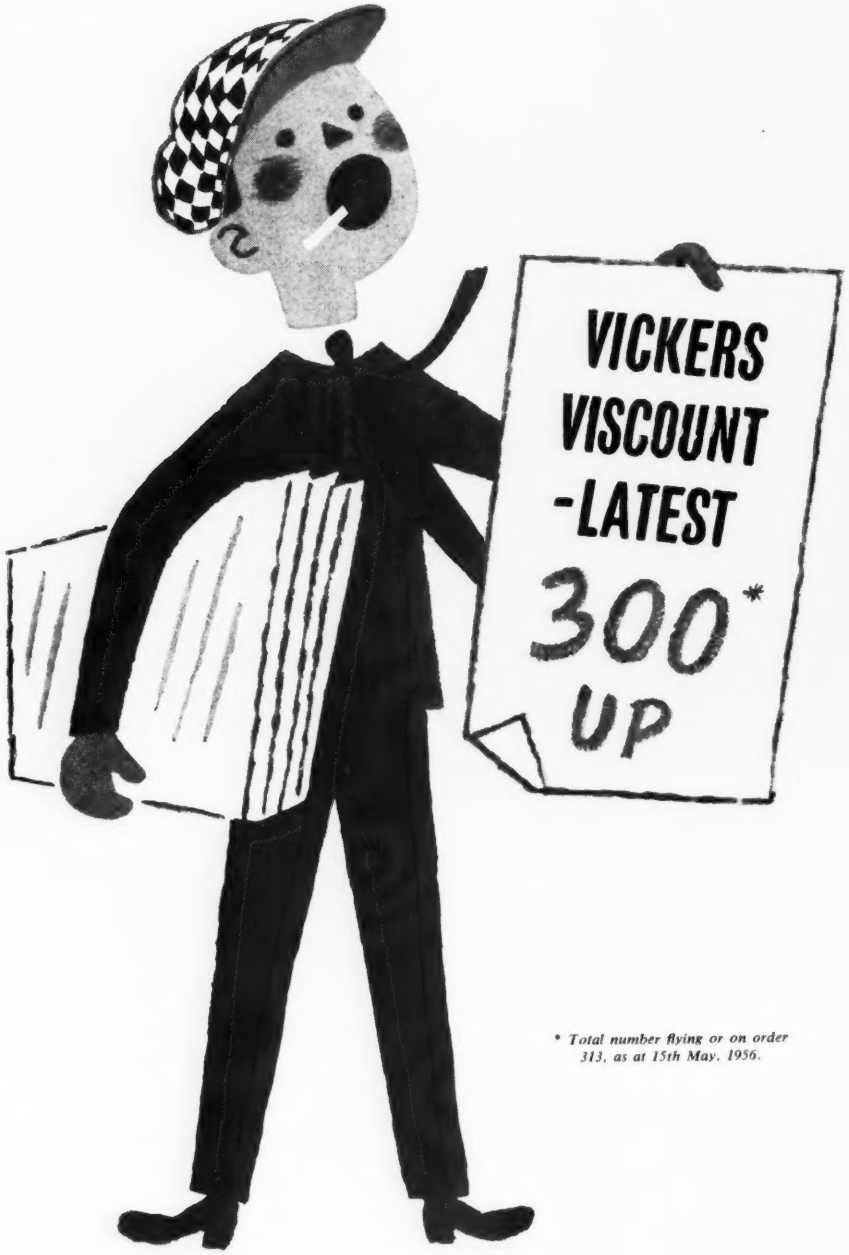

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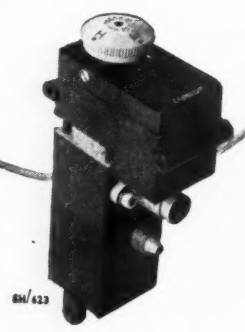

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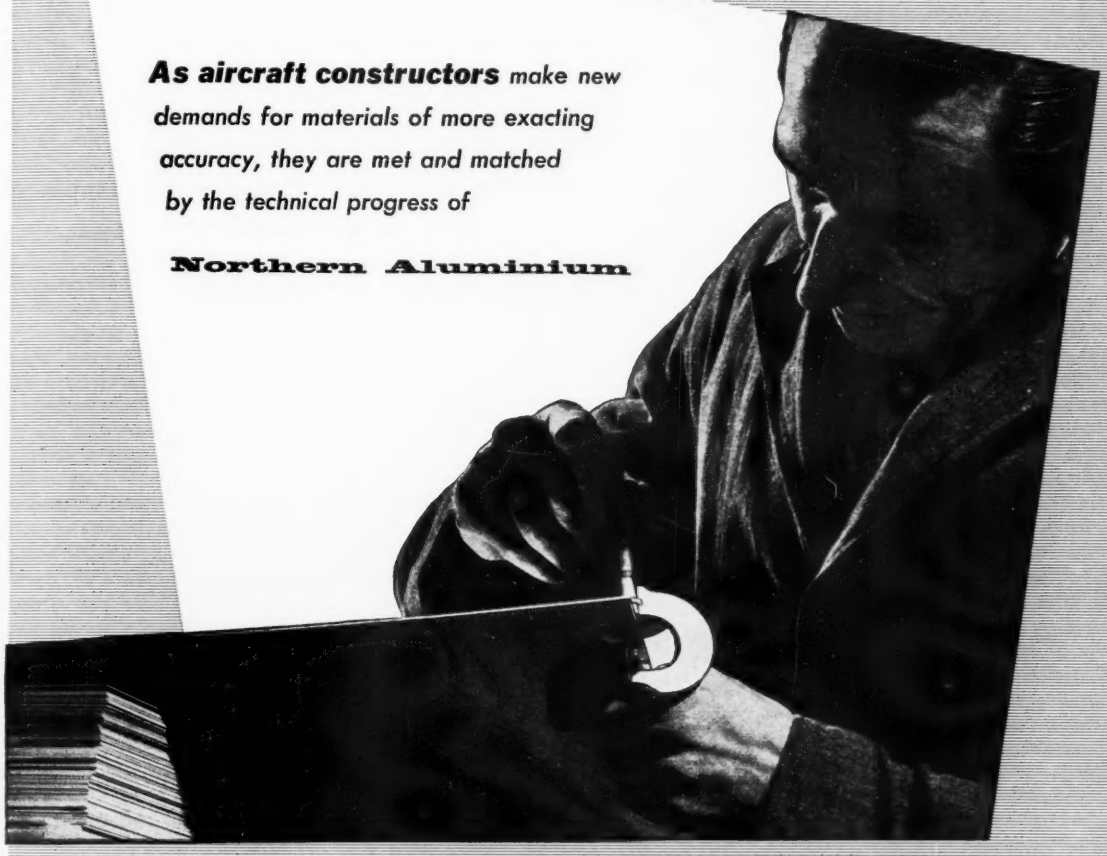
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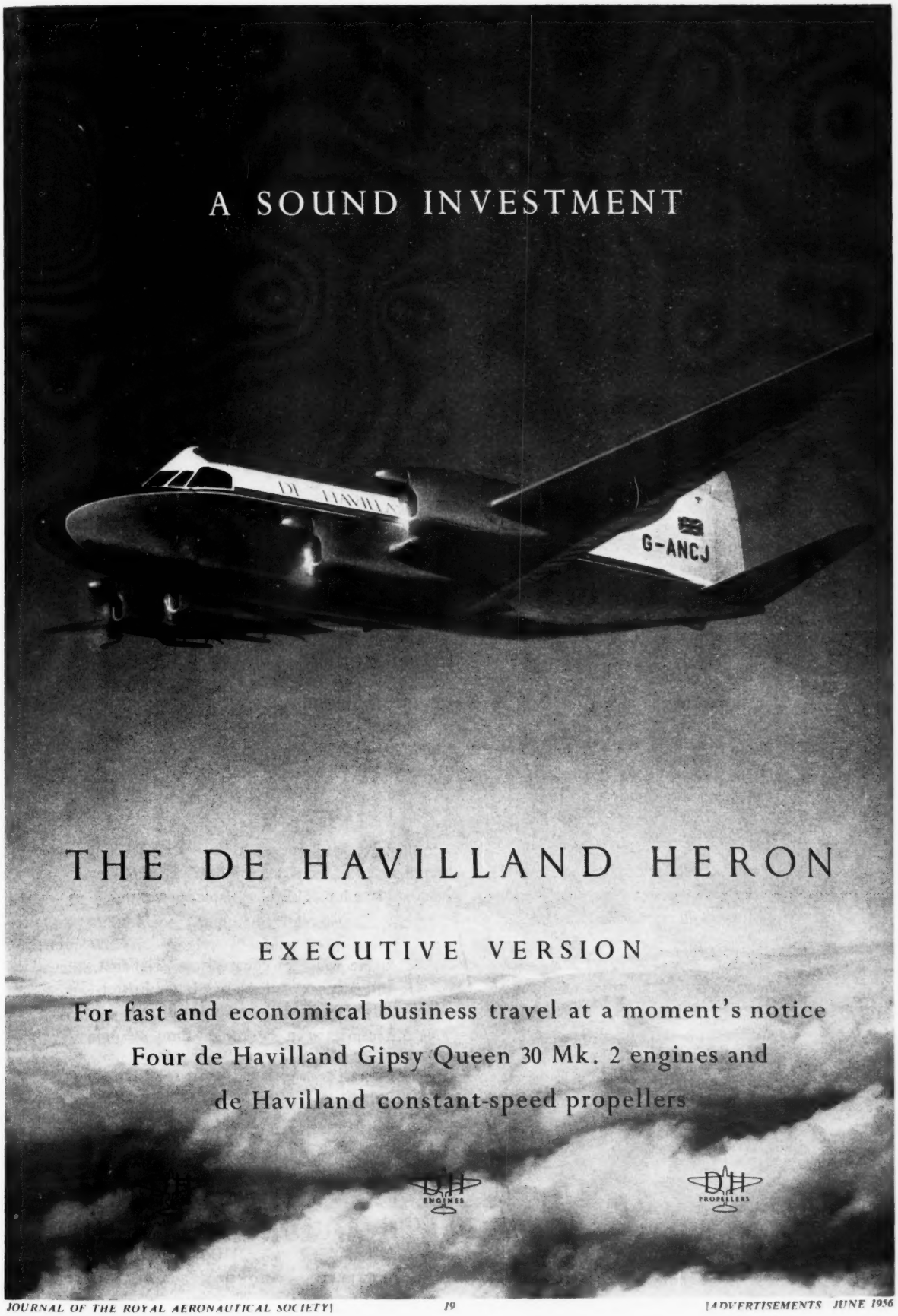
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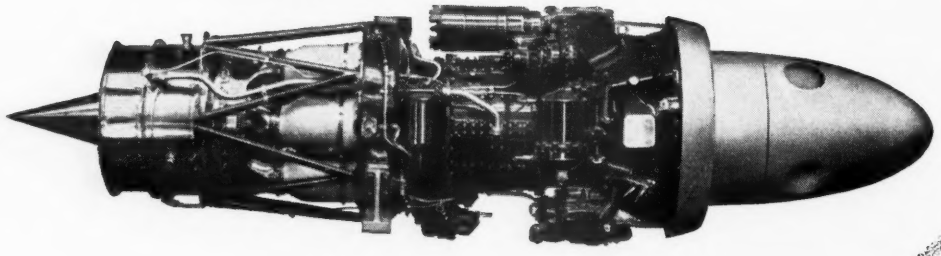

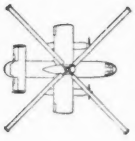

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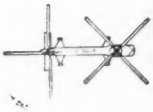

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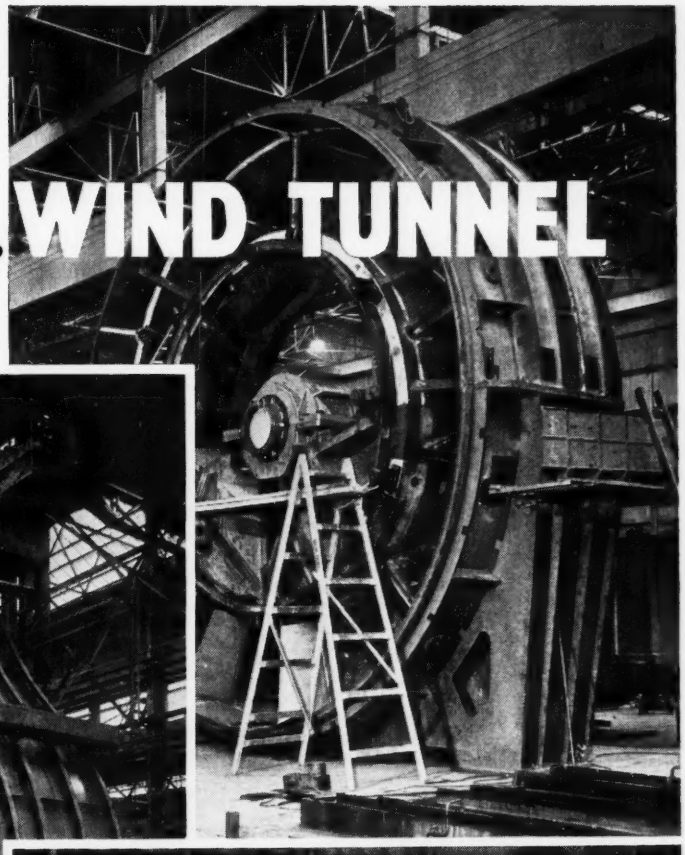

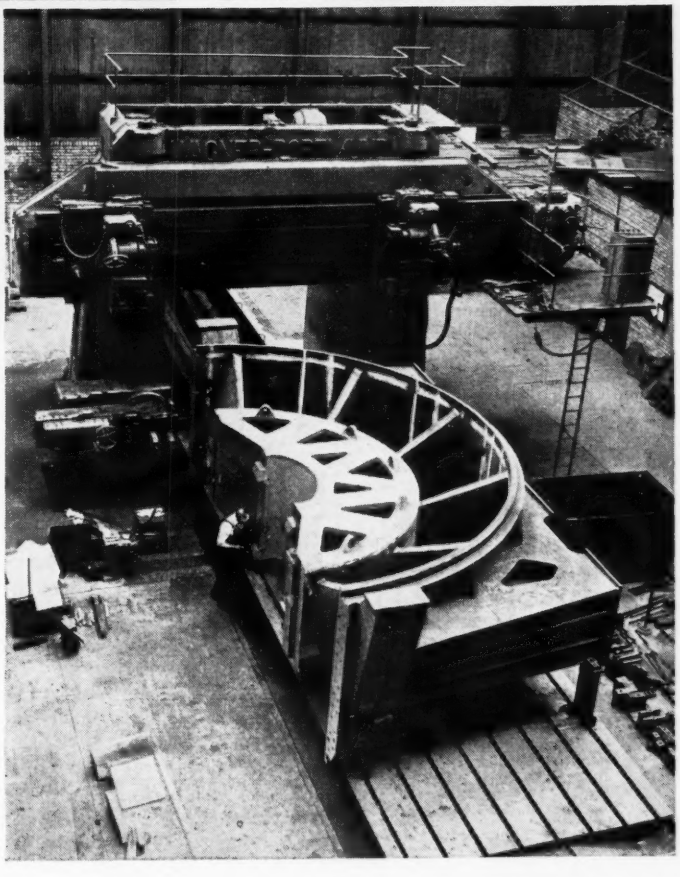

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THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

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ADDITIONS TO THE LIBRARY. REPORTS.

All communications for publication in, and advertisements for, the JOURNAL *should be addressed to the Editor,* JOAN BRADBROOKE, *A.R.Ae.S.; all communications on general matters affecting the Society should be addressed to the Secretary,* A. M. BALLANTYNE, *T.D., B.Sc., Ph.D., Hon.F.C.A.I., A.F.I.A.S., F.R.Ae.S.*

None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless otherwise stated.

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The Royal Aeronautical Society

(Founded 1866)

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NOTE: The Vice-Presidents will be elected at the Council Meeting on 31st May 1956.

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NOTICES

An annual sum of £250 is available for premium awards for papers, including Technical Notes, published in the Journal. Members and non-members of the Society are invited to submit papers on any aspect of aeronautics

President of the Society 1956-1957

Mr. E. T. Jones, C.B., O.B.E., M.Eng., F.R.Ae.S., President of the Society for the year 1956-1957, took office at the Annual General Meeting of the Society held on 10th May 1956.

President-Elect

Mr. G. R. Edwards, C.B.E., B.Sc., F.R.Ae.S., Vice-President of the Society and Managing-Director of Vickers-Armstrongs (Aircraft) Ltd., has been elected the President-Elect of the Royal Aeronautical Society for 1957-1958.

He will take office as President in May 1957.

Council for 1956-1957

The following are the newly elected Members of Council as a result of the Ballot declared at the Annual General Meeting:

*Professor A. D. Baxter, M.Eng., M.I.Mech.E., F.R.Ae.S.
*Professor A. R. Collar, M.A., D.Sc., A.F.I.A.S., F.R.Ae.S.
L. G. Frise, B.Sc., A.F.I.A.S., F.R.Ae.S.
*Sir Harry M. Garner, K.B.E., C.B., M.A., F.R.Ae.S.
*Sir Arnold A. Hall, M.A., F.R.S., F.R.Ae.S.
M. B. Morgan, M.A., F.R.Ae.S.
F. M. Owner, C.B.E., M.Sc.(Tech.), M.I.Mech.E., F.R.Ae.S.

*Re-elected.

Annual General Meeting

The Annual General Meeting of the Society was held at 4 Hamilton Place, W.1, on 5th May 1956 at which the Annual Report and Balance Sheets of the Royal Aeronautical Society and Aeronautical Trusts Limited for 1955 were approved. The Complete Report and Balance Sheets were published in the April 1956 JOURNAL.

The retiring President, Mr. N. E. Rowe, presented certain of the Society's Prizes and Awards to the recipients (a list is published with these Notices).

International Conference on Fatigue of Metals

An International Conference on Fatigue of Metals has been sponsored by the Institution of Mechanical Engineers in co-operation with the American Society of Mechanical Engineers. The main conference will take place in London from 10th-14th September 1956 and follow-up meetings will be held in New York from 28th-30th November 1956 as part of the A.S.M.E. Annual Meeting. About 70 papers will be presented for discussion, first in London and again in New York for further discussion. Copies of these will be available before the Conference.

Visits are to be arranged to centres at which research on fatigue of metals and metal components is being conducted. They will be open to those registered to attend the Conference and will take place from 17th to 21st September.

The Registration Fee is one guinea for the Conference, with an additional fee of one guinea for those taking part in the visits. This does not include the cost of advance copies of the papers.

Members of the Society have been invited to participate in this Conference, and preliminary reply forms may be obtained from the Secretary. Alternatively, application may be made direct to the Institution of Mechanical Engineers.

Garden Party, Wisley Aerodrome, 15th July 1956

All members have received a leaflet giving particulars of the Garden Party which will be held on 15th July 1956 at the Vickers-Armstrongs Aerodrome at Wisley, Surrey. An interesting flying programme will be arranged and the Royal Air Force Band will play during the afternoon. Members are advised to apply for their tickets early as this party shows every sign of being a very popular one this year.

Honorary Fellows

The Council has pleasure in announcing that the following have been accorded the honour of Honorary Fellowship of the Society:—

Sir Roy H. Dobson, C.B.E., J.P., F.R.Ae.S.
Dr. Hugh L. Dryden, Hon.F.I.A.S., F.R.Ae.S.

The Scrolls of Honorary Fellowship were presented at the 44th Wilbur Wright Memorial Lecture on 17th May 1956.

New Fellows

The following elections to Fellowship of the Society were announced at the Annual General Meeting on 10th May 1956:—

Sidney Allen
Dr. A. M. Ballantyne
Air Vice-Marshal G. B. Beardsworth
Air Cdre. George Carter
D. M. Cockburn
Air Vice-Marshal Sir Conrad Collier
F. W. David
K. H. Doetsch
Dr. J. W. Drinkwater
J. E. P. Dunning
J. L. Edwards
J. R. Ewans
D. J. Farrar
I. B. Fleming
S. F. Follett
G. C. I. Gardiner
Howard Giddings
E. W. J. Gray
Professor Charles Gurney
A. R. Howell
V. A. M. Hunt
Dr. Dietrich Küchemann
B. P. Laight
Robert McIntyre
Group Capt. J. R. Morgan
D. E. Morris
E. J. Nicholl
Air Vice-Marshal W. A. Opie
Professor J. B. B. Owen
J. G. M. Pardoe
J. J. Parkes
R. D. Peggs
A. J. Penn
Air Vice-Marshal H. D. Spreckley
W. H. Stephens
L. H. G. Sterne
P. H. Stokes
W. J. Strang
James Taylor
Professor W. J. Walker
Air Commodore A. H. Wheeler
K. G. Wilkinson

Society of British Aircraft Constructors' Educational Grants

Attention is drawn to the Society of British Aircraft Constructors' Educational Grants administered by the Society.

The Grants are designed for the assistance of young men who are unable, for financial reasons, to obtain training in aeronautical engineering. All holders of S.B.A.C. Grants are expected to qualify for a technical grade in the Royal Aeronautical Society.

Applicants should be between the ages of 16 and 18 on 1st September in the year of the award. The closing date for applications for this year is *30th June 1956*. Application forms may be obtained from the Secretary, 4 Hamilton Place, London, W.1.

Medals and Prizes of the Society

The following Medals and Prizes have been awarded by the Society. The Prizes were presented at the Annual General Meeting held on 10th May, and the Medals at the 44th Wilbur Wright Memorial Lecture on 17th May:—

The Society's Gold Medal: The highest honour which the Society can confer for work of an outstanding nature in Aeronautics, to:

Sir William Farren (*Fellow*), for his outstanding contributions to aeronautical research and development.

The Society's Silver Medal, awarded for work of an outstanding nature in Aeronautics, to:

Dr. E. S. Moult (*Fellow*), for his oustanding contributions to aeronautical engineering and, in particular, for his work in the design of aircraft engines.

The Society's Bronze Medal, awarded for work leading to an advance in Aeronautics, to:

J. W. Barnes, for his contributions in the field of aircraft instruments.

British Gold Medal for Aeronautics, awarded for outstanding practical achievement leading to advancement in aeronautics, posthumously to:

Joseph Smith (*Fellow*), for his outstanding practical achievements in the design and development of military aircraft.

British Silver Medal for Aeronautics, awarded for practical achievement leading to advancement in aeronautics, to:

J. Fenwick, for his contributions to the development of air traffic control systems.

Wakefield Gold Medal, awarded annually, at the discretion of the Council, to the Designer or Inventor of any apparatus tending towards safety in flying, to:

Group Captain W. K. Stewart, for his contributions to the design and development of aero-medical equipment.

George Taylor (Australia) Gold Medal, awarded annually, at the discretion of the Council, for the most valuable contribution read before, or received by, the Society on Aircraft Design, Manufacture or Operation, to:

R. H. Woodall (*Fellow*), for his paper "Some Trends in the Development of Aircraft Electrical and Starting Systems," September 1955 Journal.

Simms Gold Medal, awarded annually, at the discretion of the Council, for the most valuable contribution read before, or received by, the Society on any subject allied to Aeronautics, such as Structures, Meteorology or Metrology, to:

K. V. Diprose, for his paper "Analogue Computing in Aeronautics," July 1955 Journal.

R.P. Alston Memorial Prize, awarded for practical achievement associated with the flight testing of aircraft, to:

D. P. Davies, for his practical achievement in the flight testing of prototype civil aircraft.

Edward Busk Memorial Prize, awarded for the most valuable contribution published in one of the Society's Publications during the Calendar year on Applied Aerodynamics, to:

L. E. Fraenkel, for his paper "On the Unsteady Motion of a Slender Body through a Compressible Fluid" (*The Aeronautical Quarterly*, February 1955).

Herbert Akroyd Stuart Memorial Prize, awarded for the most valuable contribution to the Society's publications on Applied Thermodynamics, to:

O. N. Lawrence, for his paper "Fuel Systems for Gas Turbine Engines" (November 1955 Journal).

Usborne Memorial Prize, awarded for the best contribution to the Society's Publications written by a Graduate or Student on some subject of a technical nature in connection with Aeronautics, to:

Dr. G. N. Lance (*Graduate*), for his paper "The Lift of Twisted and Cambered Wings in Supersonic Flow" (*The Aeronautical Quarterly*, May 1955).

Orville Wright Prize, awarded for the most valuable contribution to *The Aeronautical Quarterly* of the Society on some subject of a technical nature in connection with Aeronautics, to:

K. Gunn, for his paper "Effect of Yielding on the Fatigue Properties of Test Pieces containing Stress Concentrations" (*The Aeronautical Quarterly*, November 1955).

Branch Prize, awarded for the best paper on an aeronautical subject read before the Branches of the Society, and published in the Society's Publications during the Calendar year, to:

W. Tye (*Fellow*), for his paper "The Outlook on Airframe Fatigue," the Second Barnwell Memorial Lecture (May 1955 Journal).

Royal Aeronautical Society Navigation Prize, awarded for the best paper on Navigation, including Meteorological Instruments and Test Equipment, published by the Society, to:

John Grierson, for his paper "The Evolution of Arctic Airways" (January 1955 Journal).

Pilcher Memorial Prize, awarded for the most valuable paper read by a Graduate or Student during the previous year at any meeting of the Society or its Branches, to:

H. Caplan (*Associate Fellow*), for his paper "The Investigation of Aircraft Accidents and Incidents" (January 1955 Journal).

Acknowledgment

The Council acknowledge with grateful thanks the gift of three volumes of the Proceedings of the Anglo-American Conference from Sir Arnold Hall, *Fellow*.

International Astronautical Congress

The Seventh International Astronautical Congress which is being held in Rome from 7th-22nd September 1956 is being organised by the Associazione Italiana Razzi. Anyone wishing to submit papers should send them directly to the A.I.R. in Rome before 30th June 1956. Further particulars may be obtained from the A.I.R., Piazza S. Bernardo n. 101, Roma, Italia.

International Congress on Automation

An International Congress on Automation, organised by the Department of Mechanics of the "Conservatoire National des Arts et Métiers," Ministry of Public Education, is being held in Paris from the 18th-24th June 1956. Further particulars may be obtained from the Secretary of the Congress, Department of Mechanics, C.N.A.M., 292 rue St. Martin, Paris 3. The registration fee is 2,000 frs. for members of Societies.

News of Members

J. H. Allen (*Student*) is now employed in the Farnborough Office of Auster Aircraft Ltd. as a Stressman.

G. R. Allison (*Associate Fellow*) has been transferred from the post of Inspector in Charge, A.I.D., The Gloster Aircraft Co. Ltd., to a new post as Inspector in Charge, A.I.D., Westland Aircraft Ltd.

Squadron Leader L. J. Gudgeon Bayliss (*Associate*) has been elected Vice-President of the Gloucestershire Engineering Society.

Sir John Boothman (*Fellow*) has retired from the R.A.F., and joined the Board of Kelvin and Hughes Ltd. as Technical Sales Director.

G. H. F. Brown (*Associate Fellow*) has been appointed Chief Engineer of de Havilland Propellers Ltd.

V. Cadambe (*Associate Fellow*), formerly of the National Physical Laboratory of India has been appointed Director of Research and Development at the Ministry of Defence in the Government of India.

J. Cohen (*Graduate*), formerly with the Ministry of Supply, has taken up an appointment as a Senior Aerodynamicist with Avro Aircraft Ltd. in Ontario.

Major J. L. B. H. Cordes (*Associate Fellow*) has been appointed Clerk to the Guild of Air Pilots and Air Navigators in succession to Mr. L. A. Wingfield.

L. G. Fairhurst (*Fellow*), formerly Chief Engineer of Rotol Ltd. and British Messier Ltd., has been appointed Technical Director and Chief Engineer to Rotol Ltd. and Chief Engineer to British Messier Ltd. (This replaces the paragraph in the May Journal which implied that he was no longer with Rotol Ltd.)

K. E. Farrance (*Graduate*) is now employed as a technical assistant in the Wind Tunnel Department at de Havilland Aircraft Co. Ltd.

B. G. Glass (*Associate*) has resigned his position with the Reactor Group of C. D. Howe Co. Ltd. of Montreal to join the Convair Division in San Diego of the General Dynamics Corporation as Senior Design Engineer.

A. J. Gooding (*Associate*) has been appointed Engineering Technical Grade II in the Aeronautical Inspection Directorate of the Ministry of Supply and has taken up duties at Joseph Lucas (G.T.E.) Ltd.

S. Gray (*Associate Fellow*) is now employed as Project Engineer at Stratos Division, Fairchild Engine and Airplane Corporation, Bay Shore, Long Island, N.Y.

B. E. J. Heard (*Associate*) has taken up a post on the instructional staff of the Ministry of Transport and Civil Aviation School of Air Traffic Control at Hurn Airport.

Group Captain R. C. Hockey (*Associate Fellow*), formerly Personal Executive to the Chairman and Managing Director of Blackburn and General Aircraft Ltd., has been appointed Director and General Manager of Blackburn (Dumbarton) Ltd.

P. M. Hughes (*Graduate*) has been transferred from the Project Design Office to the Wind Tunnel Department as Assistant Engineer at the English Electric Co., Warton Aerodrome.

J. C. M. Jones (*Graduate*) has left de Havilland Aircraft Ltd. to take up an appointment of Project Supervisor on the Transonic Tunnel of the Aircraft Research Association, Bedford.

P. R. Haisell-Neves (*Associate*) has resigned his post with B.O.A.C. and has been appointed full-time Lecturer in Telecommunications at the Northern Polytechnic.

Lt. Cdr. J. R. S. Overbury, R.N. (*Associate*) has been loaned by the Admiralty to Saunders-Roe Ltd. as assistant to the Chief Test Pilot.

B. A. Peaster (*Associate Fellow*) has recently taken up a position as Design Engineer at Integral Limited, Wolverhampton.

F. W. Stockhausen (*Associate*) has resigned his position as Chief Inspector with Canadian Steel Improvement Ltd., Toronto, and taken a similar post with Steel Improvement and Forge Co., Cleveland.

Dr. W. J. Strang (*Fellow*) is now Chief Designer (Fixed Wing Aircraft) Bristol Aircraft Ltd.

N. E. Sweeting (*Associate Fellow*), formerly with Keith Blackman Ltd., has been appointed Technical Sales Engineer with Air Control Installations Ltd.

R. Thompson-Holland (*Associate Fellow*) has left Bristol Aircraft Ltd., to take up an appointment with the Federal Government of Rhodesia and Nyasaland in the Central Mechanical Equipment Department.

H. Trevaskis (*Associate Fellow*), Chief Designer and Director to the Aviation Division of the Dunlop Rim and Wheel Company has been appointed Director of Development in the Central Research Division.

G. D. Turner (*Graduate*) has left Hawker Aircraft Ltd., and taken a post as Design Draughtsman with Aviation and Engineering Projects at Hounslow, Middlesex.

A. G. Willis (*Student*) has completed his apprenticeship at High Duty Alloys and is now engaged as a Planning Engineer in the Blade Department of the same firm.

Professor L. C. Woods (*Associate Fellow*) has left his lecturing post at Sydney University to accept the Nuffield Research Chair in Mechanical Engineering at the New South Wales University of Technology.

G. W. Wright (*Associate*) has left the Bristol Aeroplane Co. Ltd. to take up an appointment with the Asquith Machine Tool Corporation Ltd., as Works Director.

Graduates' and Students' Section—Visits

UNITED STATES AIR FORCE. There will have been some consternation and bewilderment among the majority of members of the Section to have heard that, despite the many notices of cancellation, a visit was made to the United States Air Force last month.

A visit had been arranged to the Third Air Force at Manston on Saturday 19th May on the occasion of Armed Forces Day. I was informed that Manston's open day had been cancelled on the day before the April Journal appeared. About fifty applications were received by post, and before these members were replied to by post, it became known that we could visit the Strategic Air Command's base at Upper Heyford on the eve of Armed Forces Day in the absence of the general public.

Thus it became possible to arrange a visit on the basis of previous applications, coinciding with notice of cancellation in the May Journal. The visit had not taken place at the time of writing this statement, but it is to be reported in the July Journal on the Section's page. The Hon. Visits Secretary offers apologies for any inconvenience caused to members. N. K. Benson.

BOSCOMBE DOWN. It is hoped to arrange a week-day visit to the Aircraft and Armament Experimental Establishment at Boscombe Down early in July. No date has yet been fixed although one is being negotiated. If the visit cannot be made in July, it will be postponed until after the usual holiday periods. Would members wishing to attend a visit to Boscombe Down write to the Hon. Visits Secretary, Mr. N. K. Benson, 14 Wakering Road, Barking, Essex, stating their grade of membership and nationality.

Proceedings of the Gas Dynamics Symposium

The Proceedings of the Symposium on the theme Aerothermochemistry which was held at The Technological Institute, Northwestern University, in August 1955, are to be published soon. The Symposium was sponsored by the American Rocket Society and Northwestern University with the co-operation of the Air Research and Development Command (U.S.A.F.). Twenty-five original research papers were given on turbulent combustion, flame stabilisation, detonation and thermodynamic laminar flames and the combustion of condensed phases. The bound volume will consist of approximately 250 pages and will cost $4.00. Particulars may be obtained from: The Technological Institute Library, Northwestern University, Evanston, Illinois, U.S.A.

Elections

The following is a list of new members and transfers of membership of the Society:—

Associate Fellows

James Arrowsmith
Edwin Bade (*from Associate*)
John Bentley
James Edmund Boden
Ilkka Erik James Bowles (*from Student*)
Leslie Harvey Bridge (*from Graduate*)
Colin Morris Britland (*from Graduate*)
David Brown (*from Graduate*)
Peter Henry Frederick Burton (*from Graduate*)
Lionel Harold Butler
Peter Henry Calder
Derek Julian Campbell
Michael Cullen Campion (*from Graduate*)
Ronald Henry Cozens (*ex Graduate*)
Jal Erach Daooo (*from Graduate*)
Thomas Bruce Cairns Davidson (*from Graduate*)
Osama Amin El-Kholy (*from Graduate*)
John Ronald Finnimore (*from Associate*)
Roy Vivian Fowkes (*from Graduate*)
George Stanley John Gibbs
Frederick Arthur Hewitt (*from Graduate*)
Henry Philip Yeulett Hitch (*from Graduate*)
George Wallace Holt (*from Graduate*)
Myra Jones
Derek Howard Jubb (*from Graduate*)
George Eric McCullagh
Kenneth John Mackenzie (*from Graduate*)
Peter Marsden (*from Student*)
Richard Ernest Mills (*from Associate*)
Colin Leslie Munro (*from Graduate*)
Thomas Dixon Nisbet (*from Associate*)
Albert Edward O'nions (*from Associate*)
Peter Frederick Orchard (*from Graduate*)
Terence Clive Owens (*from Graduate*)
Ralph Parker (*from Graduate*)
Robert Charles Pennicott (*from Graduate*)
Cyril Guest Phillips
Eric Phillip Potter (*from Graduate*)
Ronald Arthur Ramsay Rae
Mervyn Leslie Reed
Philip Hugh Robertson (*ex Student*)
Roy Richard Robinson
Christopher John Rogers (*from Graduate*)
Norman Colpoy Simpson Rutter
David Kenshett Saunders (*from Graduate*)
Gilbert Arthur Geoffrey Saywell (*from Associate*)
Gordon Sim (*from Graduate*)
John Henry James Simmonds
John Slatford (*from Graduate*)
Charles Frederick Sloper (*from Graduate*)
Ramond Edward Small
Gordon Edwin Staples (*from Graduate*)
Guy West Underwood (*from Associate*)
John Ernest Walford (*from Student*)
Stanley Herbert Whale
John Ernest Derek Williams
Peter William Wreford (*from Graduate*)

Associates

Cyril Albert Nepean Bishop
Alan William Burns
Victor Stanley Chambers (*from Student*)
Peter Frederick Norman Edwards (*from Student*)
Henry George Hammond
Bert Willis Humphries
William Ian Duncan Jordan
Basil George Malley
Henry John Albert Maplesden
Charles Marresh
William Christopher Wallace Moss
Ronald Eric Nutley
William James Milne Parnell (*from Student*)
Maurice James Seay
Leonard Smith
George William Staples
Stanley Edward Willis

Graduates

John Edward Alasia (*from Student*)
Roy Atkin (*from Student*)
Victor Baddeley
Antony James Bastick (*from Student*)
Kenneth John Bullock
Frank Graham Burger
Noel John Carew
William Frederick Dawson
Oliver Dearden
James Ian Dodds
Brian Clifford Drew
Jack Driver
Derek Lloyd Fairweather
Alexander Henry Fraser-Mitchell (*from Student*)
Roland Anthony Garth Gray
Geoffrey Leonard Hearne (*from Student*)
Michael William Mark Jenkins
Thomas Alfred Kear
David William Lawrence
Rex William Lee
John Ling (*from Student*)
Peter Barry Stuart Lissaman
Eric Lockton (*from Student*)
Charles Donald Mann
Vivian John Pennells
Malcolm Leslie Read
Trevor Bantock Saunders
Louis Edward Shenker
Frank Roy Smith
Cyril Richard Taylor (*from Student*)
Albert George Tromans
Walter Frederick Wilfred Urich
Roy Francis Williams

Students

Albert Horace Ball
Ronald Charles Barber
Terence John Barnes
Ronald Bedford
Richard William Billington
William Thomas Frederick Blakeley
Derek West Bridson
Henry Burnage
George Thomas Burton
Ronald Frederick Cass
Anton Coles
George John Corner
Gerald Augustine Cotterell
Donald Keith Craig
Peter Anthony Crooks
Robert John Cunnington
Leslie Frederick Michael de Swart
Michael Dickson
Brian David Gibbs
Terence Gervase Greville Harrison
John Brian Henshaw
John Ernest Hofstetter
Derek Holden
John Malcolm Holmes-Walker
John Homfray
Chandur Jagtiani
William Charles Keen
John Robert King
Richard McKay
Peter George McLellan
Stuart Matthews
Michael John Profit Hallahan Mercer
Katta Krishna Murthy
Brian Pawson
Alan Rothwell
Anthony Michael Salmons
David Edward Sitch
John Brian Stephens
David Neil Syme
John Michael Tank
Arthur Gilbert Ramsay Thomson
P. Raghavan Unny
Alan John Vincent
Raymond Ward
Eric James West
Roy West
Ronald Joseph Whitehouse
Keith William Woodbridge
Duncan James Woolard

Companion

Terence Charles McQuillin

Changes of Address or Appointment

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address. He would also like to know of any change of appointment.

When notifying changes please give the following particulars:—

New address (in block letters). Grade of Membership.
Name (in block letters). Old address.

New appointment—Please give name and address of employer and position held.

Changes of address must be received *before the 15th of the month* in order to be effective for the Journal for the following month.

Journal Binding

Permanent Binding

The new prices for permanent binding of Journals are: 1955 Volume (including packing and postage) £1 0s. 0d.

Previous Volumes (including packing and postage) .. .. £1 1s. 6d.

Journals, with a note of the name and address of the sender, should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the Offices of the Society.

Self-Binder Cases

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WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

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JOSEPH SMITH C.B.E., *Fellow*

1898 - 1956

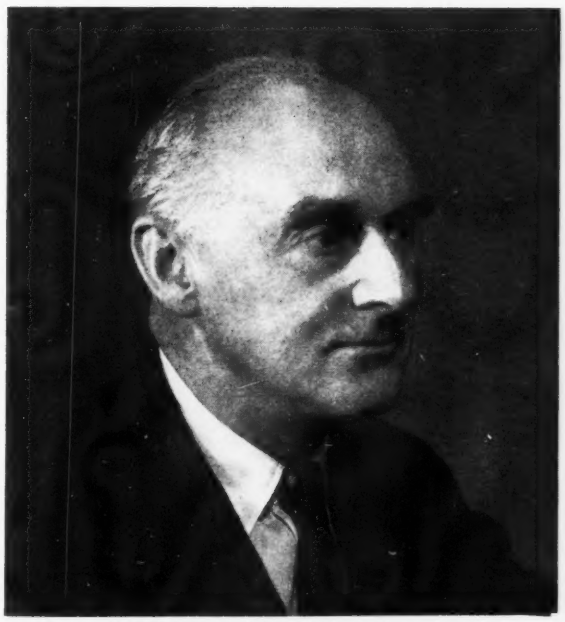
THE FACT that he was known as "Joe" to his staff, to the Aircraft Industry in general and to his friends in the Services and Ministries speaks volumes for the affection in which Joseph Smith, C.B.E., M.I.Mech.E., F.R.Ae.S., Chief Designer of the Supermarine Works of Vickers-Armstrongs (Aircraft) Ltd., was held. By his death on 20th February 1956 at the early age of 58 the Aircraft Industry has lost one of its most charming and likeable characters: it has also lost one of its most capable pioneers and a man whose whole working life was devoted to aircraft design.

Joe Smith was awarded the C.B.E. in 1946 in recognition of his war efforts and the Royal Aeronautical Society's Silver Medal in 1950 for his outstanding work on the design and development of high-speed aircraft. In 1948 he was appointed a Special Director of Vickers-Armstrongs (Aircraft) Ltd., and he served as Chairman of the Technical Board and Technical Executive Committee of the Society of British Aircraft Constructors from 1948 till 1951. He also served as Chairman of the Aircraft Industries Standards Committee, and as a member of the Engineering Divisional Council of the British Standards Institute. In 1956 he was posthumously awarded the British Gold Medal by the Royal Aeronautical Society for work of an outstanding nature in Aeronautics.

Joe Smith was born in 1898 near Birmingham, the nursery of practical engineers. He received his technical training at the Birmingham Municipal Technical School, and as an apprentice to the Austin Motor Company. He was just old enough to be involved in the First World War, and served in the Royal Naval Volunteer Reserve. The story has it that he and a few equally adventurous young men brought a naval launch *via* river and canal all the way across France, a foretaste perhaps of the other apparently "impossible" jobs he was to tackle.

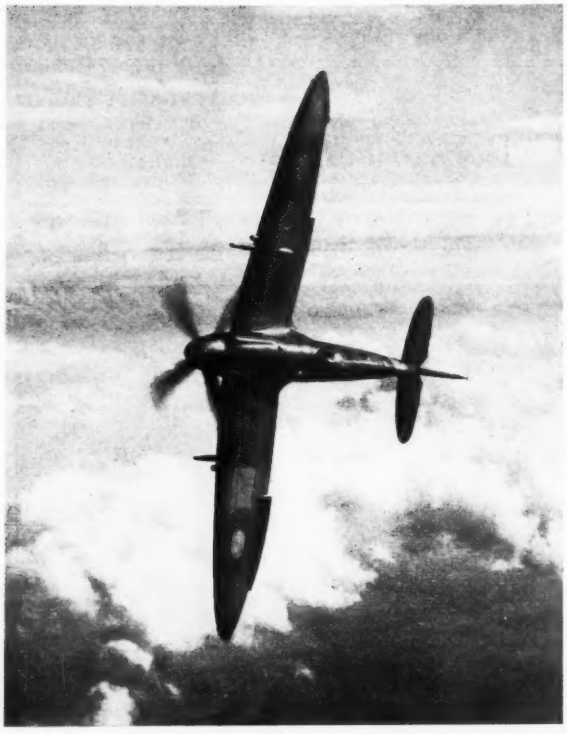
After the war he returned to Austins and completed his apprenticeship, and was then transferred to their Aeroplane drawing office, at the time when the Austin "Whippet" was being designed. This exciting new form of engineering made an instant appeal to him, and when the opportunity arose in 1921 he joined the small team of young engineers which R. J. Mitchell was then collecting together at the Supermarine Works in Southampton. He probably did not realise it, but he had joined the design team which was to absorb his life's work, and of which he was to become leader.

Being a member of Mitchell's team in the 1920's was no sinecure, but the successes which were achieved were not only a great incentive, but constituted the most valuable experience such a man as Joe Smith could possibly have wished for. His drive and energy, combined with his technical ability, soon marked him out for promotion, and in 1926 Mitchell made him Chief Draughtsman. There is no doubt that Joe made a very large contribution to the success of such historic aircraft as the "Southampton" flying boat and the Schneider Trophy racers. Two years later the Supermarine Aviation Works were acquired by Vickers Ltd., and further expansion resulted. Stirring times followed for this young design team, whose average age was only thirty. Vickers Supermarine produced four successful types of sea-going aircraft—the Scapa and Stranraer flying boats, the Seagull (later Walrus) amphibian, and culminated in the two versions of the S.6 which won the Schneider Trophy outright for Britain in 1931.



Joseph Smith, C.B.E., *Fellow*.

Mitchell decided that the Firm's experience with racing aircraft could be applied to the design of land-based fighters. The first venture, the steam-cooled F.7/30, was not entirely successful, but it led to a modified version which subsequently became the Spitfire. Mitchell died in 1937, and Joe Smith was chosen to succeed him as leader of the design team. The Spitfire had flown in prototype form and was acknowledged as a successful fighter, but a great deal remained to be done in the way of development if the full potentialities of the aircraft were to be realised.



The Spitfire 14.

It was not easy to follow in the footsteps of a genius, but Joe Smith had exactly the right capabilities to tackle the development problems involved, and to shoulder the heavy burden of responsibility. The measure by which he succeeded in carrying out his task is the conviction in the minds of those of us who worked with him that Mitchell would have been well satisfied with what was achieved. He kept the Spitfire, and later, the Seafire, in the front line of our defences throughout the war by designing a long series of aircraft with continually increasing performance and fighting efficiency. This was achieved with the help of the Rolls-Royce team under Hives (now Lord Hives) with their famous Merlin and Griffon engines, and propeller development, first by de Havillands and later by Rotols. Joe Smith was a firm believer in personal contact, and a great many meetings were held at managerial and technical levels to thrash out the problems and new ideas in order that the next mark of Spitfire should be a worthy successor to those which had gone before. Three or four new types appeared every year, and the final total was 22,758 Spitfires and Seafires in 33 different marks. Typically, Joe himself was never satisfied with the rate of progress!

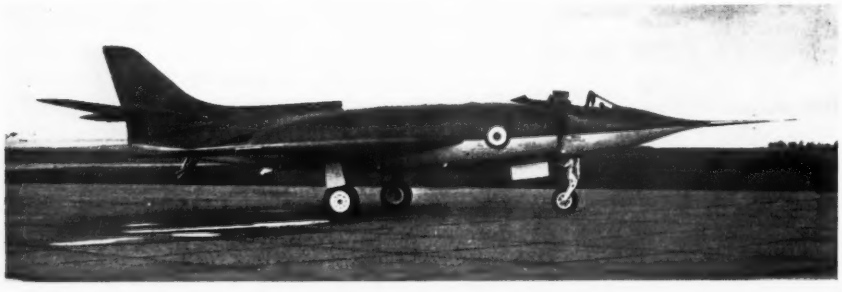
The final Spitfire was re-named Spiteful, and was the last of the firm's propeller-driven fighters. Its career was cut short by the end of the war, and Joe Smith next designed the first Naval jet fighter, the Attacker, using the Spiteful wing. Powered by the Nene engine, the Attacker saw service with the Royal Navy and took the 100 km. Closed Circuit in 1948 at a speed of 564 m.p.h.

After the Attacker came a swept-wing fighter known as the Type 510, which later became the Swift. This aircraft gained the World's Speed Record of 735 m.p.h. for Britain in 1953. Following the Type 510 came a twin-engined fighter, the N.9/47, and later, a swept-wing form of the aircraft known as the Type 525. This is now in production for the Royal Navy—the N.113—in which form it has recently successfully completed its first deck-landing trials on H.M.S. Ark Royal.

It will be seen from this brief summary that Joe's main pre-occupation has been fighter development, but he was also responsible for a post-war Sea Otter replacement, the Seagull, an amphibian flying boat which incorporated a variable incidence wing and slotted flaps, producing an oustanding range of speed.

Joe, who was responsible for so many fighter aircraft, was himself a fighter who met and overcame the technical problems which constitute the life of an aircraft designer by the application of sound engineering principles and experience, together with tenacity of purpose and unfailing good humour. In his off-duty hours the phrase "the life and soul of the party" might well have been specially invented with Joe in mind. His sincere humanity, coupled with a most lively sense of humour made him a delightful companion, yet with all this was combined the greatest possible distaste for any personal publicity, for Joe was in many ways a shy man, and the occasions on which he had to appear in public as the principal figure were ordeals to be faced. The deep sense of loss which is felt by all who knew him is due in part to the realisation of such a tragic end to a brilliant career, but also to his exceptional quality of comradeship with other men which created so much friendship and goodwill. He expected much of his staff, but their well-being was his greatest concern: particularly did he have a deep-rooted sense of responsibility for the safety of the pilots who flew his aircraft.

The world at large and the Aircraft Industry in particular can ill afford the loss of such a man.—A.B.



The Supermarine N.113 twin-jet Naval fighter.

The First Henson and Stringfellow Memorial Lecture

The Lives and Work of WILLIAM SAMUEL HENSON and JOHN STRINGFELLOW

by

A. M. BALLANTYNE, T.D., Ph.D., Hon.F.C.A.I., A.F.I.A.S., A.F.R.Ae.S.

and

J. LAURENCE PRITCHARD, C.B.E., M.R.I., Hon.F.I.A.S., Hon. Fellow.

The 23rd Main Lecture to be given at a Branch Centre was also the First Henson-Stringfellow Memorial Lecture and was given at the Yeovil Branch on the 16th February 1956. Mr. D. L. Hollis Williams, F.R.Ae.S., Chairman of the Yeovil Branch, opened the meeting and the chair was later taken by Mr. E. T. Jones, C.B., M.Eng., F.R.Ae.S., Vice-President and President-Elect of the Society. The audience, which numbered some 400, included members of the main Society and some 50 members from the Bristol and Boscombe Down Branches.

MR. D. L. HOLLIS WILLIAMS, *Fellow*, Chairman, Yeovil Branch: He had tonight to welcome many visitors, some from considerable distances and the Yeovil Branch was extremely grateful to have them present on this occasion. The Royal Aeronautical Society was founded in 1866 and had since developed into a big organisation with a number of Branches—he thought there were twenty-three altogether in the United Kingdom. The Yeovil Branch was one of the oldest of those Branches, it was born some thirty years ago. Yeovil had had many interesting and remarkable evenings during that history of thirty years but that night was particularly important because it was the first Main Lecture of the Society that had been held in Yeovil. A Main Lecture had particular significance; relatively few lectures each year were designated Main Lectures and it was customary for the President to preside. The Yeovil Branch thought on the occasion of this Main Lecture that it could do no better than associate with it the names of two pioneers in aeronautics who lived and worked in the neighbouring town of Chard, something over a hundred years ago.

To give the Lecture they were most fortunate in having the Secretary of the Society, and the past Secretary, who had access to the archives of the Society and all knowledge on the history of Aeronautics. As the tale unfolded that night, and they were honoured in that they were getting first publication of much new evidence, he thought they would be interested to see how these two pioneers, William Samuel Henson and John Stringfellow, obtained for themselves a niche in the history of Aeronautics right at the dawn of powered flight. They did not themselves achieve success, but they paved the way for others and they would see how the new evidence reflected on those two men who made a very important contribution.

Their own Branch Secretary, Mr. Lansdowne, had been making researches on his own account into local history and he had managed to find some engines that were produced by John Stringfellow, who was the great power-plant contributor in this work; Mr. Lansdowne's researches had also led to a number of members of the Stringfellow family who he was pleased to say were with them that evening.

They were indebted for the use of the Hall, in the centre of Yeovil, to the Rev. McIntyre.

He did not think it fitting that there should be a Discussion after the Lecture but he would ask one or two speakers to propose a vote of thanks.

He would now call on their local President, Mr. Wheeldon, to introduce some of the main guests.

MR. E. C. WHEELDON, Branch President: Before welcoming the visitors he would like to say he had received a telegram from the President of the Society, Mr. N. E. Rowe, which said "Deeply disappointed to be denied joining with you in the first commemorative lecture in honour of Henson and Stringfellow. This is indeed a great occasion for the Yeovil Branch. I send to you all greetings and best wishes and my own personal thanks to the lecturers."

Mr. Rowe was suffering from influenza and he was sure that all present wished him a speedy recovery.

It was a great pleasure to welcome the visitors, they were too numerous to mention each by name, but he would like to make a brief reference to several of them. Firstly, to the President-Elect of the Royal Aeronautical Society, Mr. E. T. Jones, known to many of them as the Director-General of Technical Development at the Ministry of Supply, and until recently the Principal Director of Scientific Research (Air). Mr. Jones' association with aircraft went back to the First World War when he was a pilot in the famous No. 2 Squadron of the Royal Flying Corps.

Then there was Mr. A. E. Woodward Nutt. He was Principal Director of Research and Development (Aircraft) with Mr. Jones at the Ministry of Supply and had become well-known in the many important appointments he had held in the Government Service.

Dr. A. E. Russell, who was also a visitor, was a past Chairman of the Bristol Branch of the Royal Aeronautical Society and was Technical Director of Bristol Aircraft Ltd.; he had been responsible for the design of many famous Bristol types of aeroplane and latterly for the design of the Britannia.

Mr. Raoul Hafner was Chairman of the Bristol Branch

of the Society and Chief Designer (Helicopters) at the Bristol Aircraft Ltd.

Also present was Mr. D. E. Morris, Chairman of the Boscombe Down Branch of the Society and recently appointed Superintendent of the Experimental Establishment at Boscombe Down; Mr. D. Higton, the Secretary of the Boscombe Down Branch; and Mr. R. E. Mills, the Secretary of the Bristol Branch of the Society.

Finally, he would like to welcome an old colleague, Alderman W. B. Hickman, the Mayor of Yeovil, for many years Secretary of Westland Aircraft Ltd., who was now in his second term of office as Mayor of the Borough. He would now ask the President-Elect to introduce the lecturers.

MR. E. T. JONES, *Fellow*, President-Elect: He felt that it was a pity Mr. Rowe, the President, was unable to be present because he had been looking forward to that evening. The Chairman had told them how important this meeting was. Indeed it was unique from one or two points of view. First, it was the first Main Lecture the Royal Aeronautical Society had held in Yeovil. Secondly, it was the first Lecture in which a former Secretary of the Society had combined with the current one to prepare and give a Lecture. Thirdly, it was the first of a series of commemorative meetings or lectures and it was appropriate that this Lecture should be given in Yeovil for several reasons, not least of which was the fact that the Yeovil Branch was the second oldest Branch of the Society.

Captain Laurence Pritchard did not need any introduction from him, or from anybody else that knew anything about Aeronautics. However, he did seem to have done the right thing during his life. He managed to get his parents to send him to Dulwich and then on to Cambridge. He joined the Royal Naval Air Service in the First World War and later, in 1925, he became the Secretary of the Royal Aeronautical Society. They all knew the good work that he had done in the twenty-six years that he was Secretary, from 1925 to 1951, but what some possibly did not know was that during the bad periods of the Society, after the First World War, Laurence Pritchard was prepared to keep on working for the Society without pay. He wondered how many today would do that for their jobs. Captain Pritchard was awarded the C.B.E. for his work with the Society and very well merited it was; he was partly, if not mainly, responsible for the Americans setting up the best counterpart they could of the Royal Aeronautical Society, that became the Institute of the Aeronautical Sciences. He was very active during the Second World War and was responsible for the formation of the Committee which was used very much by the then Ministry of Aircraft Production, for giving advice on many subjects.

Last year one might have thought, having attained the age of seventy, he would stop roaming round the world but, no, he went to America and gave a series of Lectures.

Dr. Ballantyne was a Scotsman and also seemed to have done the right things too. He was educated in Glasgow and, being a good Scotsman, he stayed there for some time as a Lecturer. Then he came on to London as, of course, most Scotsmen did at some time or other in their history, they came south. Then in 1951 Dr. Ballantyne took over from Captain Pritchard as Secretary of the Society. He would ask whichever one was giving the Lecture, either their former Secretary or their current one, to give the First Memorial Lecture on the lives and work of William Samuel Henson and John Stringfellow.

FOREWORD

(By the Secretary of the Society)

On the Lecture Programme of the Society this Memorial Lecture appeared as "The Stringfellow Memorial Lecture," for it was the original intention of commemorating solely John Stringfellow. I was pleased to accept the invitation of the Yeovil branch to deliver the first lecture, for, although I had but a superficial knowledge of Stringfellow, I did know that some few biographies had been written; from these it was my intention to cull the necessary facts and so place before you the Stringfellow story.

The previous writers were aviation historians, and to such I had never aspired.

However I thought that it might be possible to contribute something by a thorough examination of the historical letters and clippings, which, over the years, have come into the possession of the Society. All that I foresaw was a possibility of expanding an existing story; to add something to Davy's words on Stringfellow, ". . . . and Stringfellow carried it to a point of limited success when he demonstrated in 1848 that a model could fly under its own power."

That, then, was my task as I saw it.

But, as Burns has so aptly put it, "The best laid schemes of mice and men gang aft agley."

I found the examination of the papers in the possession of the Society had been done already, although the result of these searches and researches had not been made public.

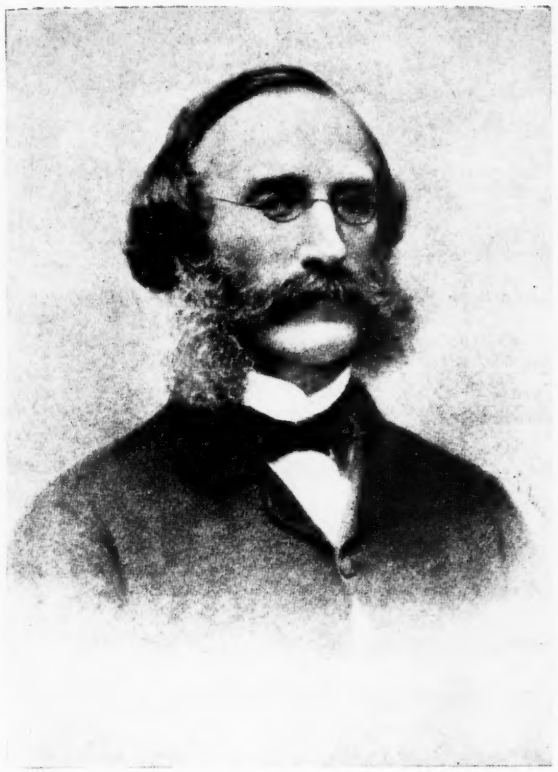
Many will know that Captain J. Laurence Pritchard, since his retirement from the Secretaryship of the Society, has devoted a considerable portion of his time to the reading and research necessary for a History of the Society, upon which he is engaged.

Pritchard has found many facts hitherto unknown or even erroneously stated; he has determined such indeterminate phrases as "it is thought" or "it is said," and the picture of Stringfellow, although perhaps not yet crystal clear, is not so befogged as before.

It is apparent from Pritchard's work that Stringfellow and Henson must be considered together, and thus the "Stringfellow Memorial Lecture" has been altered to the "Henson and Stringfellow Memorial Lecture."

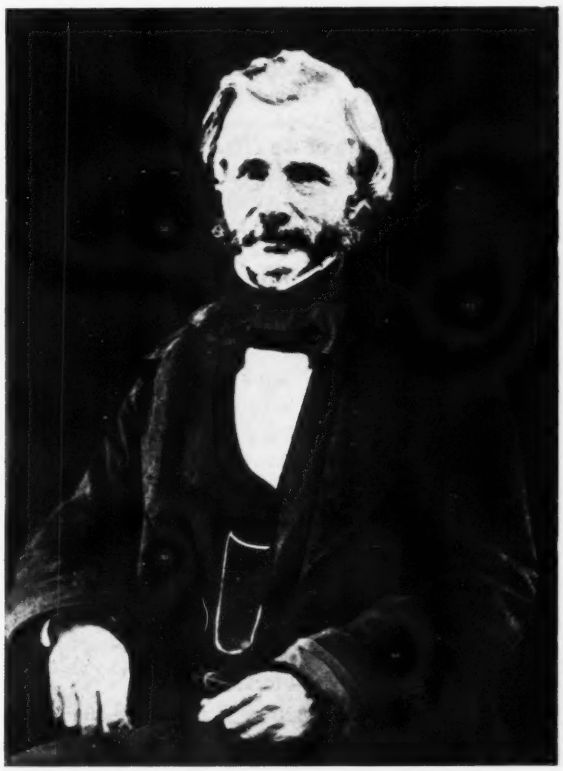
Captain Pritchard wished to make me a gift of the results of his researches but although I could not say with Virgil ". . . timeo Danaos et dona ferentis" * I think that you will agree with me that it is he who should tell of his work, which gives a new view on the work of Henson and Stringfellow.

**Equo ne credite, Teucri. Quidquid id est, timeo Danaos et dona ferentis.* "Men of Troy, trust not the horse! Be it what it may, I fear the Danaans, though their hands proffer gifts."



United States National Museum Photograph

William Samuel Henson
1812-1888



John Stringfellow
1799-1883

1. Introduction

In the comparatively short story of Aviation it is of interest to note how often two co-experimenters have added their names to the calendar of aeronautical progress.

The very beginning, indeed, of the story, is due to the brothers Joseph and Etienne Montgolfier who sent their hot air balloon into the mystery of the sky in 1783; and the brothers Robert, a year later, who began the construction of the first hydrogen balloon, the elder Robert making the first hydrogen balloon flight with Charles. The brothers Tissandier, Albert and Gaston; Eugène and Jules Godard in France and the Spencer brothers in Great Britain are other well-known names in lighter-than-air history.

In the heavier-than-air field Henson and Stringfellow, Thomas Moy and Shill, the brothers Wilbur and Orville Wright, and others more recent are known for their experiments and achievements.

It is with the work of Henson and Stringfellow that this first Memorial Lecture is concerned, and it is not without interest that a former Secretary and the present Secretary of the Society together place on record what is old and what is new about both men, yet leave them both as aeronautical figures. *In the text of this paper what is new in British accounts (or in a nearer sense, unpublished in this country) is printed in italics.*

In the histories of the work of Henson and Stringfellow in this country the strong tendency has been to give a greater credit to Stringfellow than to Henson. Part of this has been due to the fact that Henson left England in 1848 to live in America where he died in 1888, and his name became a subsidiary one in the accounts of his and Stringfellow's work and experiments in Chard in 1843-48.

John Stringfellow's reputation in aeronautical history rests upon three claims. One, that he designed and constructed the first engine-driven model aeroplane to make a free flight; two, that he designed and made a steam-driven model triplane capable of free flight; and, three, that he made a small steam engine with the highest power/weight ratio of its time.

This lecture is concerned with the evidence for these three claims; with Stringfellow's general approach towards solving the problem of flight; and with the inter-dependence of himself and William Samuel Henson.

There is no known *contemporary* evidence, published or unpublished, in the possession of the Aeronautical Society, or within its present knowledge, which gives any account of the flight of Stringfellow's engine-driven model of 1848. Such an account would be weighty evidence for any assessment of Stringfellow's achievements.

The first statement publicly made was in January 1869, by F. W. Brearey, Hon. Secretary of the Aeronautical Society, just on 21 years after the event; and the second by F. J. Stringfellow, John Stringfellow's son, at the end of 1892, 44 years after the event and 9 years after the death of his father.

On these two statements are based *every* account written since of the 1848 flight; and part of F. J. Stringfellow's version is in fact copied from that of F. W. Brearey.

More or less detailed accounts have been given of the work of Henson and Stringfellow by the Royal Aeronautical Society, the Science Museum, by J. E. Hodgson, by Pritchard and others.

All these accounts are inaccurate in many particulars. All of them have drawn firm conclusions on fragmentary and doubtful evidence. All have been written without reference to certain letters of F. W. Brearey and John Stringfellow and others in the possession of the Society; and all were written before the remarkable research work of Paul Johnston, Director of the Institute of the Aeronautical Sciences, into the life of Henson, which was published during the Second World War.

2. William Samuel Henson

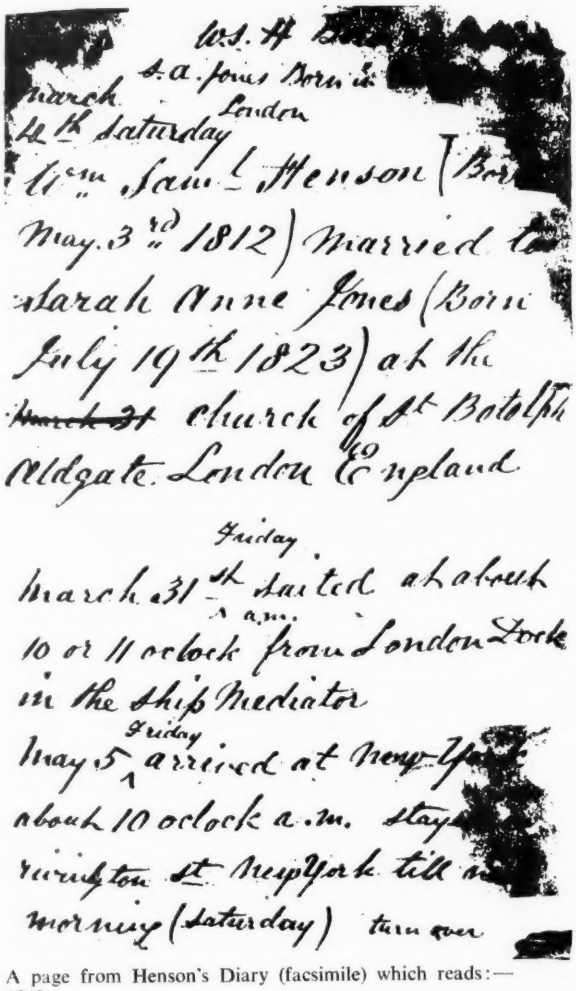
Most writers of aeronautical history have stated that Henson went to America in 1848,and there disappeared. Hodgson accepted[21] the Society's account in the Aeronautical Classics[18], which gives the date of the disappearance as 1849 and Henson's date and place of birth as 1805, in Leicester, as do the official handbooks of the Science Museum. Brearey in his 1869 account suggested Henson left England in 1847, while F. J. Stringfellow says the end of 1847 or early in 1848. Davy who wrote the Science Museum account, had more justification than most for the date 1849. "There has been some doubt," he wrote, "as to the actual date of his departure but it is now established through the agency of his son, the late Mr. Edward F. Henson, that he emigrated in 1849, living at first in the vicinity of Philadelphia; and that he did not go to Texas as stated."

The son was as mistaken as the rest. The date of Henson's birth, the place, the time of leaving England, and where he went when he arrived in America, are all wrong, and these errors of fact have led historians to conclusions about Henson and Stringfellow which can now no longer be sustained.

In the course of his researches Johnston discovered[25] *Henson's diary (now a treasured possession of the Institute of the Aeronautical Sciences). It revealed that he was born on May 3, 1812, in Nottingham and left England, to land in New York on May 5, 1848. There he joined his father who had settled in Newark, New Jersey. "The directories of the City of Newark carry continuous record of his residence there, beginning with the issue of 1850, down to the year of his death, 1888," records Johnston.*

Henson became an American citizen in 1853 and died on March 22nd, 1888. His father had returned to England some years before, and died in Nottingham in 1879, and is buried there. Johnston noted that he was an inventive genius, "a manufacturer of lace, leaving a trail of patents for devices to improve the machinery and processes of manufacture." William Samuel was his son by his first marriage. The "Nottingham Guardian" of November 5, 1870, states with reference to some improvements in carpet machinery that "he was thoroughly robbed by the Yankees."

"Henson," Johnston says, "was primarily a mechanic—and his interests were completely catholic. All his life he was continually thinking up new ideas in mechanics and in machinery. To him no mechanism


W.S.H. Born
S. A. Jones Born in
March 4th Saturday London
Wm. Saml. Henson (Born May 3rd 1812) married to Sarah Anne Jones (Born July 19th 1823) at the church of St. Botolph Aldgate London England
Friday March 31st Sailed at about 10 or 11 o'clock from London Dock in the ship Mediator
Friday May 5 arrived at New York about 10 o'clock a.m. Stayed Rivington St. New York till next morning (Saturday) turn over

A page from Henson's Diary (facsimile) which reads:—
1848
W.S.H. Born 1812
S. A. Jones Born in 1823
March 4th Saturday London
Wm. Saml. Henson (Born May 3rd 1812) married to Sarah Anne Jones (Born July 19th 1823) at the church of St. Botolph Aldgate, London England
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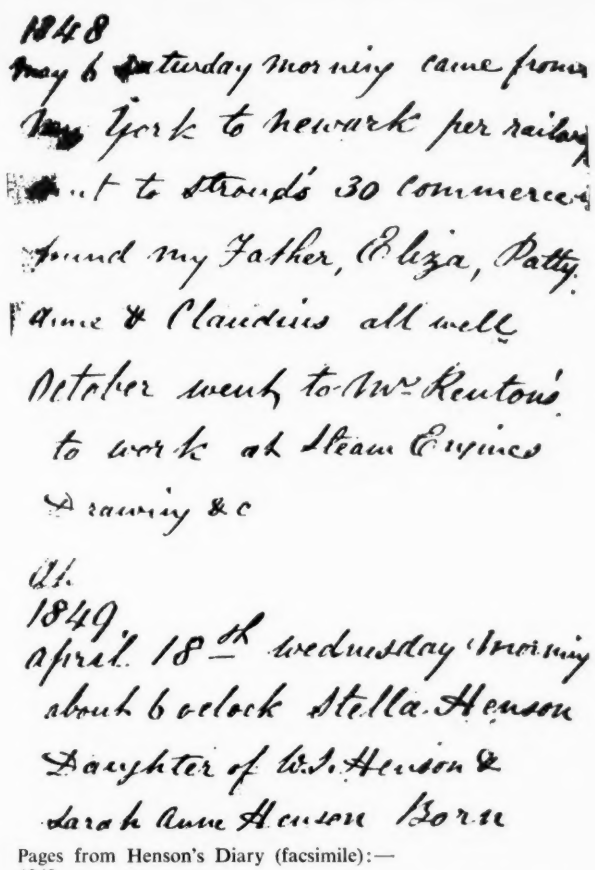
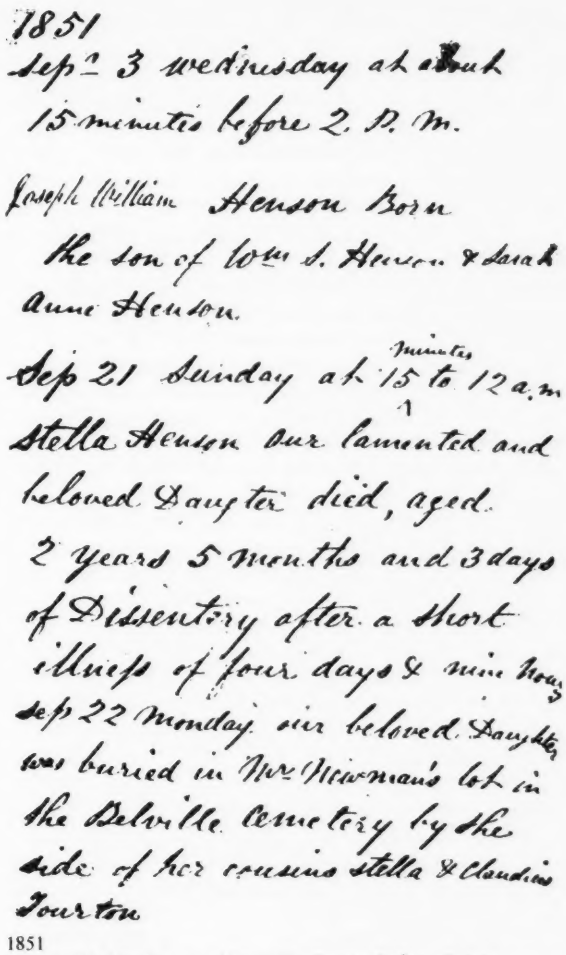


1848
May 6 Saturday morning came from New York to Newark per railway went to Stroud's 30 Commerce. Found my Father, Eliza, Patty, Anne & Claudius all well
October went to Mr. Kenton's to work at Steam Engines, Drawing &c
1849
April 18th Wednesday morning about 6 o'clock Stella Henson Daughter of W. S. Henson & Sarah Anne Henson Born.



1851
Sepr 3 Wednesday at about 15 minutes before 2 p.m.
Joseph William Henson Born the son of Wm. S. Henson & Sarah Anne Henson.
Sep 21 Sunday at 15 minutes to 12 a.m. Stella Henson our lamented and beloved Daughter died, aged 2 years 5 months and 3 days of Dissentory after a short illness of four days & nine hours.
Sep 22 Monday our beloved Daughter was buried in Mr. Newman's lot in the Belville Cemetery by the side of her cousins Stella & Claudius Tourton.

was perfect. Each new device that he saw apparently challenged him to improve upon it. He would work intensively upon it for a while, then drop it—a new razor, an aeroplane, a breech-loading cannon, a method for water-proofing fabric, an ice machine, a spring-board, or a device for cleaning cisterns. Toward the end of his life he became intensively interested in the mechanics of the Universe. He observed, he read, he speculated, and he wrote on astronomical matters.

"His only known published work is a treatise on astronomy, privately printed in Newark in the Spring of 1871. It is short, only 28 pages, but its scope can be gauged from the title: 'The Great Facts of Modern Astronomy with an Exposition of what they teach comprising the Formation of the Planets and their Satellites, solution of the Law of Distances, Theory of Light and the Sun Spots.'

"Evidently Henson was not one to cramp his imaginings by limiting his subject."

Henson married, only two months before he left England, Sarah Ann Jones. *He had seven children of whom one, a son, was still alive at the time Johnston was making his researches.* All this information and much more now printed for the first time in this country, is new. In Henson's diary, for example, under the date October 1848, is the entry, *"Went to Mr. Kenton's to work at steam engines, drawing, etc."*

3. John Stringfellow

John Stringfellow was born on December 6, 1799, in Attercliffe, near Sheffield. *His father, William Stringfellow, died on November 9, 1842*[3], *two months after W. S. Henson took out his famous patent No. 9478 for his Aerial Steam Carriage.*

The father not only had a great interest in science, but also in mechanics, and had a small laboratory of his

own and workshop in which he made, among other things, small working models and instruments.[1]

It was from his father that John Stringfellow must have picked up his mechanical dexterity. He learnt the trade of bobbin and carriage manufacturer, and became well-known in the lace industry for his work. About 1820 he left Nottingham (where he had been apprenticed) for Chard and set up on his own account.

Like his father he had wide interests and is known to have paid special attention to electrical matters. The manuscripts of two of his lectures have survived, one dated June 17, 1847 and the other just the year, 1847. The first is a general historical lecture, illustrated with many experiments. The second is entitled "Electricity and Galvanism in relation to the treatment of Diseases."

Much attention was being paid in those days to the treatment by electricity for relieving pain and Stringfellow became well known for his Pocket Galvanic Battery. Both his lectures show a wide knowledge of electrical phenomena, but that on the treatment of diseases by electrical methods revealed the ignorance of the workings of the human body, so prevalent at the time. He knew many of the well known electricians, and made most of the apparatus with which he demonstrated his lectures. He was an excellent photographer, played a lively part in politics at the time of the passing of the Reform Bill, and served on the Chard Council from 1833 to 1847.[12]

When he first took an interest in the possibility of flight, or when he first met Henson, are dates completely unknown. In the account of his life, at the time of his funeral in Chard, an account clearly to some extent supplied by his family, the local paper, the *Chard and Ilminster News*, made no mention of any meeting at any time between Henson and Stringfellow. Yet it is known that they were working together for five years at least, and probably more, in the 1840s.

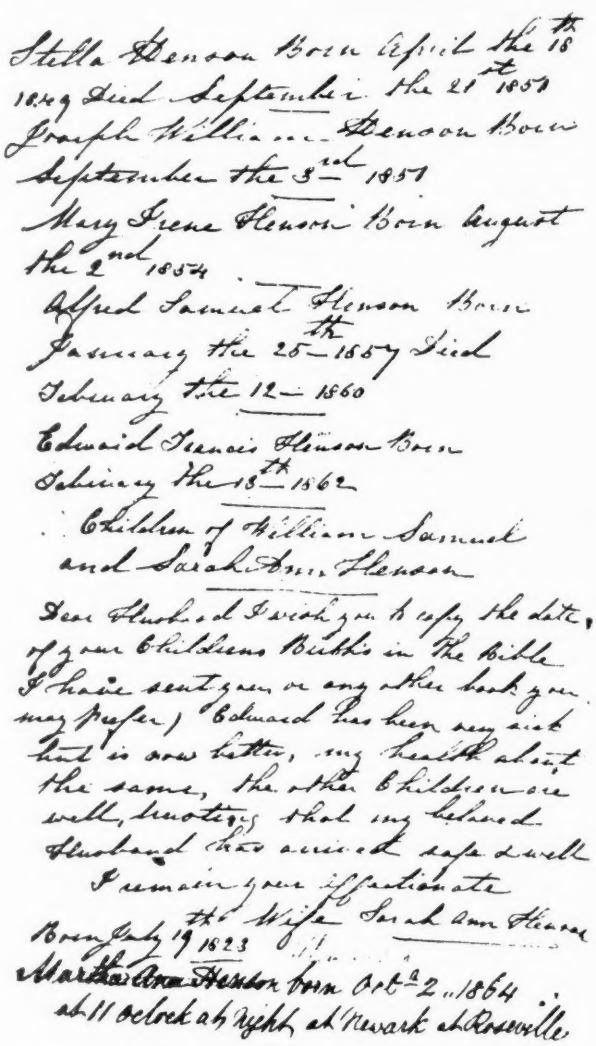
John Stringfellow died on December 13, 1883. The part he played in attempting the solution of the flying problem is considered in what follows.

4. Early Relationship

"The relationship between Henson and Stringfellow before and during the years of their active collaboration has never been entirely clear," says Johnston. "So little has been known of Henson's early life, and the reason for the breaking up of the partnership, that historians have arrived at their conclusions from extremely slender data."

Neither Brearey nor F. J. Stringfellow, the chief sources of information, gave any date, though Brearey suggests that Henson's Aerial Steam Carriage, of 1842, was the result of collaboration between them. The Society's account of 1910, suggests a considerably earlier date, as does Hodgson.

Hodgson, indeed, boldly states of Henson[21] "He was living with his father at Chard when John Stringfellow moved there in 1820. Mutual interests in engineering and aeronautics brought the two men together, and when shortly afterwards Henson—doubtless


Stella Henson Born April the 18th 1849 Died September the 21st 1851
Joseph William Henson Born September the 3rd 1851
Mary Irene Henson Born August the 2nd 1854
Alfred Samuel Henson Born January the 25th 1857 Died February the 12th 1860
Edward Francis Henson Born February the 13th 1862.
Children of William Samuel and Sarah Anne Henson
Dear Husband I wish you to copy the date of your Childrens Births in the Bible I have sent you or any other book you may prefer. Edward has been very sick but is now better, my health about the same, the other Children are well, trusting that my beloved Husband has arrived safe and well
I remain your affectionate
Wife Sarah Ann Henson
Born July 19th 1823
Martha Ann Henson born Octr 2 1864 at 11 oclock at night at Newark at Roseville

A page (facsimile) from Mrs. Henson's Diary:—
Stella Henson Born April the 18th 1849 Died September the 21st 1851

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in the hope of furthering his aeronautical aims—went to live in London, they kept up a correspondence."

It is puzzling to know on what grounds Hodgson could have made such a definite statement. *In 1820 Henson was only eight years of age, and Stringfellow himself only twenty.* There is no evidence that Stringfellow had any interest at all in aeronautics at that time. He was at the beginning of a career on his own in Chard in the manufacture of lace-making machinery. At eight years of age Henson might have been flying a kite, but hardly could he have been said to have been interested in aeronautics. The same error was made by Davy of the Science Museum in as definite terms.

Johnston gave chapter and verse to show that these kind of statements were not true. Writing of Henson's father, he says, "He was apprenticed at an early age to a 'framework knitter' in Nottingham (probably about 1798). He married Martha Charge in 1807. His progress was rapid, for by 1812 (the year William Samuel was born) he was elected a burgess of Nottingham and was already talked of as an 'inventive genius.' . . . . About 1820 he and his growing family moved to Worcester, where he became a manufacturer of lace, leaving a trail of patents for devices to improve the machinery and processes of manufacture. His first wife died sometime in the early 1830s and shortly thereafter he married again and moved to Chard. Between 1845 and 1848 he moved to America, where William Samuel joined him in 1848."

It is not unlikely that the Henson and Stringfellow families knew one another in Nottingham, for they were both in the lace trade, but there is no definite evidence.

When Stringfellow died in 1883, the local paper, THE CHARD AND ILMINSTER NEWS, *wrote a long and eulogistic memoir in which, as already noted, there was no mention of Henson in any way.*[12] *Nor was there in the other two local papers, the* WEST OF ENGLAND EXPRESS[13] and the SOMERSET COUNTY GAZETTE.[14] *The latter two papers made, indeed, the grossly inaccurate statement about Stringfellow. "In 1842 and 1843 he designed a machine, which was duly patented, but certain defects were observable in it, and he continued his studies down to 1868, when he attended the annual meeting of the Aeronautical Society at the Crystal Palace, with the machine."*

The first concrete evidence of Henson being in Chard is in a letter dated July 10, 1835, written on paper headed W. S. Henson, Lace Manufacturer, Chard. On October 1st, 1835, a patent was granted to him, as "Wm. S. Henson, machinist, of Chard," for improvements in machinery for lace manufacture. At that time Stringfellow had been a member of the Chard Town Council for some two years.[25]

It was curious, to say the least, that this complete absence of reference to Henson should have occurred in the obituaries especially as Brearey had given details of the association in 1869. It is a factor in assessing Stringfellow's work, for much of the information given in the local obituary notices must have come from local people and relatives, who cannot be completely absolved of blame for the omission.

5. Henson's Patent of 1842

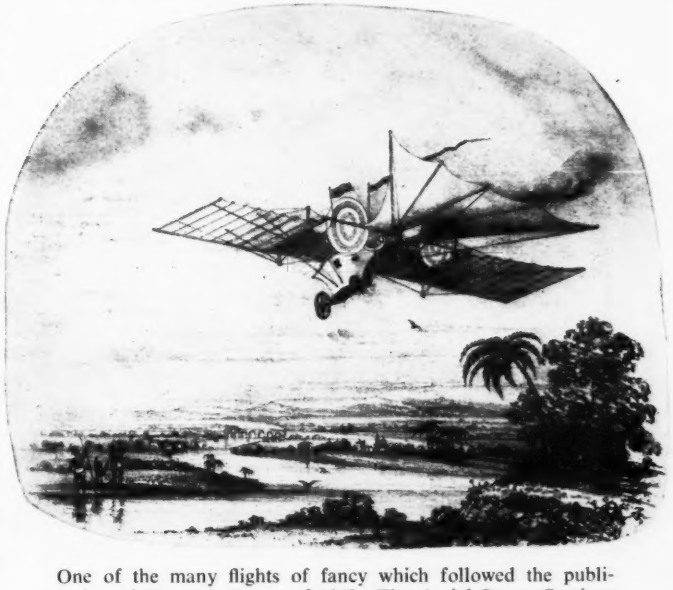
In the whole history of aeronautics, from 1773 to 1907, there are few instances of publicity so great as that which followed the publication of Henson's Patent Specification No. 9478 of 1842. The interest was world-wide and fanciful pictures of Henson's Aerial Steam Carriage appeared in papers and weekly magazines on the Continent, in the United States and Great Britain, and in India with still more fanciful stories of the new Air Age which was opening.

The story is too well known to be given again in detail here. It may be found in most of the authorities quoted, particularly Hodgson and Davy. Here the story is emphasised more from the point of view of the collaboration of Henson and Stringfellow. The Henson Patent is printed in full in the Appendix to this paper for the first time in any of the Society's publications.

Brearey wrote in 1869, "The plan resulted from conversation between Henson and Stringfellow at the residence of the latter-named gentleman in Chard, Somerset," a suggestion not made by F. J. Stringfellow, nor repeated by Brearey later in the Memoir he wrote of his friend in the 1883 *Annual Report*. Davy was strongly of the opinion that Stringfellow did not take any part in the actual design work and stated, "Henson was apparently wholly responsible for the design work recorded in his patent specification of 1842 and the necessary detailed plans which accompanied it."[22]

The only statement that Stringfellow took any part in the 1842 project was the one quoted, of Brearey's and is unsupported by any other evidence.

An examination of the Patent and its drawings makes it clear that it was not just an imaginative idea with sketches, but one such as an engineer would have put forward—without having the full data he would like to have—after study of the problem in the light of the ideas and knowledge of his day.



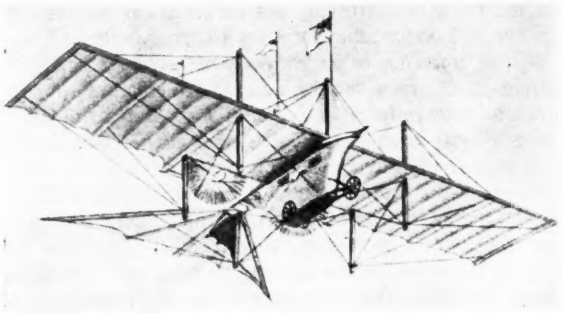
One of the many flights of fancy which followed the publication of Henson's Patent of 1842—The Aerial Steam Carriage over Africa.

The Society's account of 1910 states that Henson began, in 1840, experiments with gliding models and a light steam engine. Davy makes the same statement, without any hint of source and adds, " The engine seems to have cost him endless trouble in spite of the advice and assistance of Stringfellow, who supplied him with parts for his boiler."

The account does not go so far as to suggest that Stringfellow was responsible for inventing the form of the steam engine, though it does suggest that he had probably put the idea into Henson's head of " the peculiar cone construction in the boiler."

On what authority that statement is made is not known. In view of other evidence there is probably no truth in it. On January 10, 1842, Henson wrote[18] from London to Stringfellow, after apologising for not writing earlier, " I waited to give you some more particulars respecting my little engine . . . . . The boiler consists of two cones, 4½ inches dia. and 7 deep. From the widest part downwards the cylinders are let into the cones in the manner mentioned to you when you were in town; the cones are like the tin I showed you at that time, having the upper part large enough to hold one of the cylinders above the waterline at wide part

" I find your cylinders will hold three times the quantity that mine will hold, consequently there should be something more than double the quantity of heating surface, but it will be advisable not to have double the weight of water, a gallon of water weighs about 10 lb. One quart of water is about the proper quantity for your boiler. It won't last long, it's true, but that does not matter. My engine is considerably heavier than it ought to be, in addition to which it holds more water than is necessary. This is against me, but still it is very powerful for its weight, and I have no doubt about making it act. I have not yet got my model sufficiently advanced to have a fly, but I continue as sanguine as ever as to the results.

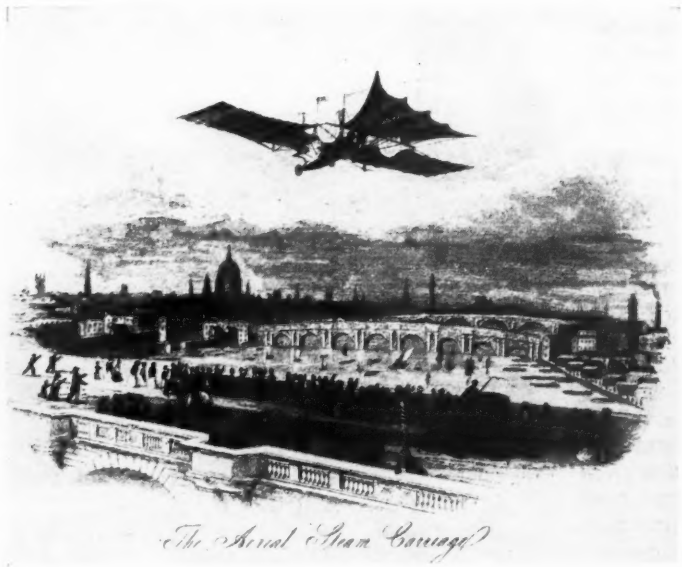


Henson's Aerial Steam Carriage.

" I think you had better make the boiler to consist of several small cones, each holding a very small quantity of water, so as to get about 2½ times the quantity of surface with the same quantity of water—such as 6 or 8 cones of about 3 or 2 inches dia. at the broad part, well studded with copper wire. My engine, with water and fuel altogether with the fireplace weighs about 10 lb. and I am quite sure an engine may be made of double the power with the same weight, including everything, and I know also that you can do it and will. I wish much I could have had your engine for my present model, as it would assist so much in making up for those natural defects which all models possess more or less." *

First of all it should be noted in this letter that Henson says, " I have not yet got my model sufficiently advanced to have a fly, but I continue as sanguine as ever as to the results."

*Henson took out his patent No. 9478 on 29th September 1842. The Patent gives a complete description of his engine, together with four diagrams. The Patent was not published until April 1843.



Another of the engravings which were published of the Aerial Steam Carriage—showing it flying over London.

He was clearly making his own model, without the assistance of Stringfellow.

In his letter Henson begins by saying he had waited "to give some more particulars of *my* engine," and continues "the boiler consists of two cones," and adds "I think you had better make the boiler to consist of several small cones."

There is no suggestion here that the idea came from Stringfellow. When Henson's Aerial Steam Carriage project was put forward it received immense publicity. *One report from the* PICTORIAL TIMES *in April 1843, referring to the engine, reads*

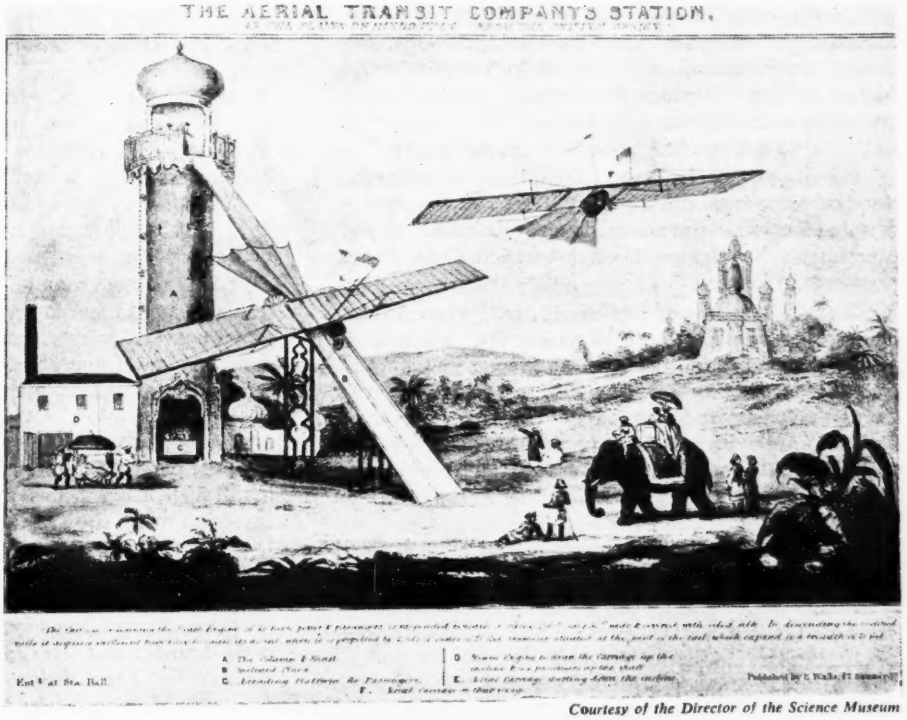
"Besides the great lightness and simplicity of its parts, the steam engine is remarkable for the novelty both of its boiler and its condenser: it is indeed by the singular skill with which he has constructed them that Mr. Henson has transformed the ponderous steam engine into a contrivance fitted for travelling the regions of the air. The boiler consists of a number of hollow cones placed around and about the furnace, with their truncated points downward. They are large and numerous enough to present about 100 sq. ft. to the action of the fire . . . ."

Stringfellow's name was not mentioned in any of the descriptions of the aerial machine or of the boiler, any more than it had been in the patent. If the "remarkable novelty of the boiler and its condenser" had been due to Stringfellow, then it is still more remarkable, both then and over the years after, that Stringfellow himself made no comment, nor did his family in letters or articles. Nor, indeed, did Stringfellow ever claim any novelty in the "peculiar cone construction" as suggested in the Society's Aeronautical Classics No. 5.

This question of the engine requires more careful consideration than it has hitherto received, for any suggestion that it was an original design by Stringfellow must be discounted. There is no doubt about Stringfellow's unusual ability as a mechanic, and one who was able to adapt existing designs and materials to produce a lighter and better result than most. The Society's account and Davy's both draw attention to the peculiar method of construction "specified by Henson in 1842, but in all probability evolved by Stringfellow," who apparently took no interest in Henson patenting the idea and taking all the credit! Henson, indeed, was specific in his patent claim "I claim the mode herein explained of constructing steam boilers applicable to locomotive machinery, such as above described . . . ." His patent also uses the words "I will also describe my improved construction of steam-boiler . . . . the peculiar construction of which constitutes the second part of my Invention." No room for a misunderstanding here, surely!

The *Mechanics' Magazine*[3] for April 1st, 1843, commenting on Henson's project, said caustically, "The truth is, that we can discover nothing of importance in the present scheme which has not been proposed, and even tried, before; with the exception, perhaps, of the steam boiler; and even that seems to be rather a combination of various known contrivances (as Viney's cones, Williams' conducting pins, etc.) than an embodiment of any original conceptions of Mr. Henson's own." Or, one might add, of Mr. Stringfellow, if writers so many years afterwards were correct in their assumptions!

One might add here, too, that Dr. Hureau de



A Fanciful Representation of an Aerial Station—The proposed take-off of the Henson Aerial Steam Carriage was even more spectacular than a four-engined jet of the present day. Hence the saying "Elephants never fo get."

Courtesy of the Director of the Science Museum

Villeneuve, editor for so many years of L'AERONAUTE, *commenting on Stringfellow's engine shown at the Crystal Palace in 1868, remarked in the November 1868 issue of his Journal that "though made with great care it embodied no new principle."* [9]

Johnston states that when Henson's diary was found there was also discovered Henson's copy of John Wise's book on Aeronautics in which the 1842 Aerial Steam Carriage was discussed. Against the statement by Wise that "It was seriously contemplated to build one after his model, with which to cross the Atlantic," Henson had written, "This is mere newspaper talk, I never thought anything so absurd. I knew that the steam engine had to be remodelled to make steam navigation practicable and I still farther remodelled steam boilers and produced the lightest engine ever built which on a small scale was still insufficient; the engine developed* $\frac{1}{4}$ *the power of the steam altho it was operated with a cut off."*

Henson's letter of June 10, 1842 ended with the words "I wish I could have your engine for my present model, as it would assist so much in making up for those natural defects which all models possess more or less."

If this is read carefully it suggests that whatever engine Stringfellow had, it was not intended to go into a model aeroplane, for then it would have become a model engine which would not have "assisted in making up for those natural defects, which all models possess more or less."

The story of the exploitation of Henson's ideas and the formation of a Company is well known and amply documented. The Company proved a failure. The promotor was a lawyer named Columbine, and the publicity agent a journalist named Marriott. Both had shares in the Company with Henson and Stringfellow, though the prospectus only referred to "the Originator of 'an Invention,' which if ultimately successful will 'be without parallel even in the age which introduced to the world the wonderful effects of gas and steam.'"

The appeal for funds was completely unsuccessful (for the prospectus was in the vaguest possible terms) despite the wide-spread publicity, including model experiments by Henson at the Adelaide Gallery and elsewhere in London.

The *Morning Herald* for July 10, 1843, reporting on these experiments, after saying the first model had almost shaken itself to pieces in working, stated[2] *"The second model engine is certainly a very novel thing. It consists of one cylinder only, and with its frame, water, fuel and fire box weighs but 6 lb. This engine it is said performs 1,500 revolutions per minute. It does much credit to Mr. Henson, as well as the above Institution, at which it has been made."*

In its issue of August 4, 1843, however, the *Morning Herald* changed its tone completely. *"The experiments which have been made during the last two months at the Adelaide Gallery, with respect to this much be-puffed vehicle of communication between distant nations, would appear to be almost conclusive against the remotest probability of its ever performing an indoor trip beyond the rate of some 10-15 miles per hour."*

Henson had a steam engine model, continues the report, but it was too heavy. A lighter model of the same dimensions was constructed. It had the lightest possible ribs covered with blue silk, and a much lighter and more powerful engine. An inclined plane was formed at one end of the Gallery in which iron wires were placed longitudinally for the purpose of catching the machine when it fell, or if it should really fly the whole length of the gallery. In the first experiment as soon as it left the inclined plane it flopped. "Not a single foot did it fly," in the words of the report. The wire stays of the wings of the machine were broken.

A second attempt was made with a still lighter engine. This was also a failure. "A third, fourth, and it is not rightly known how many attempts were made, but with an invariable result. Directly the plane was left the model came down flop . . . Up to the present time, therefore, the world is no nearer flying."

The machine was said by the HERALD *to have a surface of 40 sq. ft. and to weigh 14 lb.*

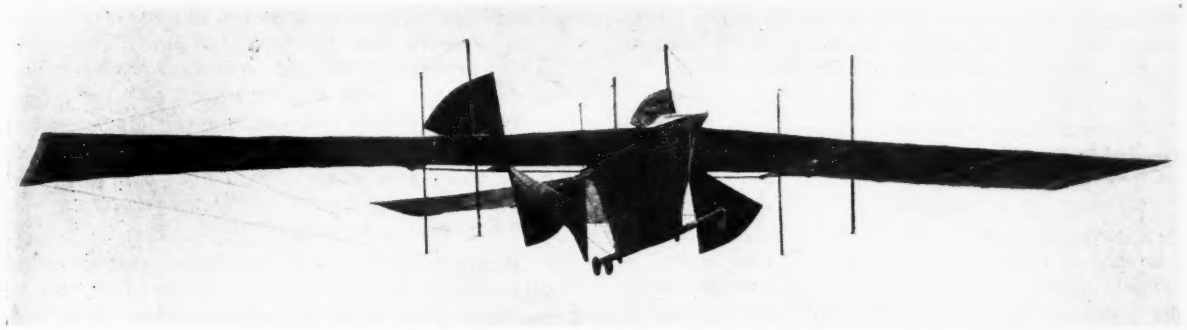
John Stringfellow, in a letter written to Brearey *on September 21, 1868, said, "Henson did full as much as could be expected with the means he had and in the infant state of the science. He made a spring model which illustrated the principle and several hand models and if his experiments at the Adelaide Gallery were abortive they were not fruitless. The thing might have been different had the parties spent less money in rousing the public's expectation and more in enabling Mr. Henson to carry on the experiments and mature his plans. Henson was a friend of mine and of course I knew something of the treatment he received from the parties he was connected with."*

Where, later, Stringfellow came in, according to Davy, was as one "who had been promised the work of constructing a machine when funds were forthcoming."[22] This is borne out by a letter of Henson's to Stringfellow, from London, dated November 18, 1843. Stringfellow had evidently been asking about the delay in coming to terms. Henson wrote,

"I think you are quite right in your views. I knew how you would feel in the matter, and I said distinctly that whoever I might get to carry out the matter would expect to have control of it during progress and very liberal treatment also, and that, in fact, neither of them (Columbine or Marriott) would know anything about it until it was done; if it succeeded they would have to fulfil the contract, if not, they would hear no more about it. I shall leave a note at Columbine's to-day to ask him for a rough copy or sketch of the terms for you . . . Don't you think the buying of the patent—I mean Columbine and Marriott shares—would be a good move?"

What Stringfellow's reply was has not apparently been found. *But on July 25, 1845, he wrote to Henson*[25], *"I received two notes from Marriott; in the one received this morning there was a proposition which*

**History and Practice of Aeronautics.* John Wise. Philadelphia. 1850.



The Henson-Stringfellow model 1844-47 (restored). *Courtesy of the Director of the Science Museum*

I give you under and to which I believe Columbine is agreeable, that is to divide the patent interests into 12 as follows, Henson 4/12, Columbine 4/12, Marriott 2/12, Stringfellow 2/12—this Marriott thinks equable and just. I refrain from giving you my opinion on the subject as I should wish your opinion on it candidly and unbiased."

This gave Henson double the shares of Stringfellow, which Marriott thought equable and just. Nor does Stringfellow protest, but leaves the decision to Henson.

Neither Brearey nor F. J. Stringfellow mention this letter or give any hint that Stringfellow's services were valued at half those of Henson. When this letter was written he and Henson had been working together for some eighteen months on a model of the Patent, and this letter indicates the relationship of the two men.

6. The Collaboration of 1843-47

Before 1843 was out it was clear that the Company promoters, Columbine and Marriott, had failed in their object and Henson and Stringfellow were wondering what would happen next.

In December 1843 the two men signed an agreement "to construct a model of an Aerial Machine to be employed in such manner as the parties shall consider best and most profitable."

Clause 1 read: "It is agreed, if considered necessary, to take out patents for the same jointly, but be it understood that this agreement does not extend to England except for such parts as are improvements upon patent already taken out in England"*.

This makes it clear that Henson was solely responsible for the patent of 1842, for this was the only aeronautical patent, as far as the two signatories were concerned.

The first public account of any kind, as far as is at present known, dealing with the work of the two experimenters together under this agreement, appeared in January 1869, in the *Popular Science Review*, in the paper written by Brearey.[10] That was twenty-five years after the signing of the agreement, on information probably supplied by John Stringfellow. The point is discussed later.

*See Appendix II for a copy of the full agreement.

"In 1844," wrote Brearey, "they together commenced the construction of a model; Henson attending chiefly to the wood or framework, and Stringfellow to the propulsive power, for which, after trial of other effects, he adopted steam. This model, completed in 1845, measured twenty feet from tip to tip of wing, by three and a half feet wide, giving seventy feet of sustaining surface in the wings, and about ten more in the tail. The weight of the entire machine was from twenty five to twenty eight pounds."

F. J. Stringfellow, in 1892, added further details of these early experiments.[15] Brearey, in his 1883 memoir, merely copies from what he had himself said in 1869. There is no doubt about the experiments or the efforts, by Stringfellow, to produce a small, light and reliable steam engine. *John Stringfellow made, in his lifetime, many steam engines of various sizes and for various purposes and, in correspondence with members of the Aeronautical Society his son refers to them as being for sale, after his father's death. One, for example, is mentioned in a letter to B. F. S. Baden-Powell (then a member of the Council and afterwards a President of the Society). The date of the letter is February 8, 1894.*

"I have for disposal a much larger engine with two cylinders 2½ or 3 inch diameter with copper boiler (cones). It was begun by my late father for a company for the relief of Paris by Balloon, but the siege was raised before it was completed."

Baden-Powell, failing to buy it, F. J. Stringfellow offered it for sale to another member, G. Crosland Taylor, four years later, in 1898. In an earlier letter, dated October 14, 1895, F. J. Stringfellow, writing to Taylor, said "In the early forties my late Father constructed a boiler on the same type for a common road Steam Carriage. It is made of copper, 7 cones about 4½ inches diameter at top end and about 20 inches long. It was contained in an iron case with fireplace and, complete, weighed about 40 lbs. The measurement is about 2 feet 9½ inches to the top of the dome and width about 13 inches. Will stand a pressure of 300 lbs. I have the boiler now and would be glad to sell it cheap."

This last letter is significant, not only because of its reference to what John Stringfellow was doing in the early forties, the period now under review, but for

another reference towards the end of the letter, "I do not see how a patent could be taken out for the boiler as a similar one was patented in '42 altho never worked."

That evidently referred to Henson's patent!

Crosland Taylor, writing to Lawrence Hargrave on December 12, 1896, shed an interesting light on another of Stringfellow's engines.

"I went about four weeks ago," he wrote, "to see F. J. Stringfellow at Crewkerne (I daresay you have his pamphlet on Flying machines) to see his cone boiler. It is made of cones about the following proportions, which are connected up top and bottom to a receiver and 3 square feet are supposed to equal one h.p. and will get up 100 lb. of steam in 4 minutes or even less. I was told 2½ minutes. However it is to come to our works to test for the purposes of a motor car—it was made 40 years ago and is all thin copper and contains 6 square feet heated surface.

"April 27, 1897. I have just found this letter to you in my works desk, thought I had sent it and I must have been interrupted and forgot it however. The above boiler contains nearly 7 square feet of surface and weighs 15 lb. and is 16 inches high, 17 inches long and 5 inches wide, 28 cones and a receiver on top. I am going to make a boiler like it only stronger and larger for a motor car which will have four cylinders, direct on to the wheels."

The model experiments were carried out on Bala Down, near Chard. F. J. Stringfellow copied part of his account from Brearey's of 1869, and added details of his own. In Brearey's account, as already stated, much must have come from John Stringfellow. *In Brearey's copy letter book, is a copy of a letter he wrote to John Stringfellow on September 6, 1868. This letter, like many others of Brearey, John Stringfellow and his son F. J. Stringfellow, does not appear to have been previously quoted.*

"Application has been made to me to write an account for a popular periodical of the more prominent novelties exhibited at the Crystal Palace to be accompanied with illustrations. Foremost is your aerial machine. Would you mind setting down and writing for me a short history of your commencement with Henson, how you worked and your ideas—the trials—and supposed cause of failure—your next attempt—and trial at Cremorne—results—cause of your abandoning that form and taking to superposed planes—your reasons for not letting it free at the Crystal Palace . . . .

"If you had time I should like to describe your engine also, commencing with your former attempts to secure lightness with a photograph if you can, of engine and boiler. Don't be too particular about the style. I only want the matter and I will put it into shape if you will kindly give the statement in the order in which I have written it. They want it about the 10th but I am afraid you cannot do it by that time as I want to make it interesting if not amusing."

But Stringfellow's reply has not been found.

However, his letter to Brearey, dated September 21, 1868, giving further information and enclosing photographs, and referring to the work of Henson and himself is available. This letter is quoted at some length, when considering the 1848 experiments of Stringfellow. It is a most important letter and certainly it has never been quoted by any of the modern writers.

Brearey acknowledged the letter the day he received it, September 22, 1868. "I am now embodying the substance of your remarks and I must note as I go on those things which require a little clearing up for what strikes me may strike others."

Brearey's account is quoted before that of Stringfellow's son, because it was nearer the event, and the two men were in direct communication about what happened. Similarities or differences in the two accounts will be noted as necessary.

The beginning of Brearey's description ("in 1844 . ." to "twenty eight pounds" p. 373) has already been noted. This was copied by F. J. Stringfellow, except that he omits the weight.

"As pictorial illustrations of the machine were widely published at the time," wrote Brearey, "it is not thought necessary to reproduce them, especially as a succeeding attempt, hereafter depicted, bears a great resemblance to it; the important difference existing in the improved method of construction."

Brearey is here referring to the model of the Henson Aerial Carriage project which the two men were making.

"The principal feature was the very large sustaining surface in proportion to the weight, which as we have seen in reference to M. de Lucy's experiments,* was far in excess of the requisite conditions. To support this weight, it was necessary to propel the plane surface at an angle against the resisting air, and it is evident, that in proportion as the speed imparted was increased, so might the angle be decreased.

"It was necessary to provide initial force; accordingly an inclined plane was constructed, down which the machine was to glide, and it was so arranged that the power should be maintained by a steam engine, working two four-bladed propellers, each three feet in diameter, at a rate of 300 revolutions per minute.

"A tent was erected on the Downs two miles from Chard, and for seven weeks the two experimenters continued their labours—not, however, without much annoyance from intruders. In the language of Mr. Stringfellow, 'There stood our aerial protégée in all her purity—too delicate too fragile too beautiful for this rough world; at least, those were my ideas at the time, but little did I think how soon it was to be realised. I soon found, before I had time to introduce the spark, a drooping in the wings, a flagging in all the parts. In less than ten minutes the machine was saturated with wet from a deposit of dew, so that anything like a trial was not possible by night. I did not consider we could get the silk tight and rigid enough. Indeed, the frame work altogether was too weak. The steam engine was the best part. Our want of success was not for want of power or sustaining surface, but for want of proper adaptation of the means to the end of the various parts.'

*Published in the Annual Report for 1869.

Chard June 10th/68

Dear Sir

I am sorry if I have said any thing to mislead you In the letter you refer to I stated I would make it go from one end to the other of the building by some means this I can do by a guide line and certainly in 1st experiments I should not attempt to liberate it till it had thoroughly proved capable of Self-Control whatever shortcomings there may be at 1st there is nothing in the principle but what may eventually be surmounted—I wish Mr. Wenham could have seen the Model, he would understand it at once.

There is no room sufficiently large for experimenting in this neighbourhood or I should not have kept my old Models rotting for years.

Yours very truly

J. Stringfellow

Stringfellow's letter with reference to Triplane demonstrations at the Crystal Palace Aeronautical Exhibition of 1868:—

Chard June 10th/68

Dear Sir

I am sorry if I have said anything to mislead you. In the letter you refer to I stated I would make it go from one end to the other of the building by some means this I can do by a guide line and certainly in 1st experiments I should not attempt to liberate it till it had thoroughly proved capable of Self-Control whatever shortcomings there may be at 1st there is nothing in the principle but what may eventually be surmounted—I wish Mr. Wenham could have seen the Model, he would understand it at once.

There is no room sufficiently large for experimenting in this neighbourhood or I should not have kept my old Models rotting for years.

Yours very truly

J. Stringfellow

AERONAUTICAL SOCIETY OF GREAT BRITAIN
MAIDENSTONE HILL
BLACKHEATH S.E.

Sept 6th 1868

My dear Sir

Application has been made to me to write an account for a popular periodical of the more prominent novelties exhibited at the Crystal Palace – to be accompanied with illustrations. Foremost is your Aerial Machine. Would you mind sitting down and writing for me a short history of your commencement with Henson; how you worked out your ideas; – the trials – & supposed cause of failure – your next attempt – trial at Cremorne – results – cause of your abandoning that form & taking to superposed planes – your reasons for not letting it free at the Crystal Palace.

I have the photograph of which they must make a wood cut.—

If you had time I should like to describe your Engine also, commencing with your former attempts to secure lightness with a photograph if you can, of Engine and Boiler. Dont be particular about the style. I only want the matter & I will pull it into shape if you will kindly give the statement in the order in which I have written it.

Yours truly
F. W. Brearey.

They want it about the 10th but I am afraid you cannot do it by that time as I want to make it interesting if not amusing.

The first two pages of Brearey's Letter to Stringfellow asking for particulars of his 1843-48 experiments at Chard and Cremorne. The letter in full is:—

AERONAUTICAL SOCIETY OF GREAT BRITAIN
MAIDENSTONE HILL
BLACKHEATH S.E.
Sept 6th 1868

My Dear Sir

Application has been made to me to write an account for a popular periodical of the more prominent novelties exhibited at the Crystal Palace to be accompanied with illustrations. Foremost is your Aerial Machine. Would you mind sitting down and writing for me a short history of your commencement with Henson; how you worked out your ideas;—the trials—& supposed cause of failure—your next attempt—trial at Cremorne—results—cause of your abandoning that form & taking to superposed planes—your reasons for not letting it free at the Crystal Palace.

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Yours truly
F. W. Brearey.

They want it about the 10th but I am afraid you cannot do it by that time as I want to make it interesting if not amusing.

" Many trials by day down inclined wide rails showed a faulty construction, and its lightness proved an obstacle to its successfully contending with the ground currents."

It will be noted that here Brearey quotes Stringfellow's actual words, which praise his engine but disparage the framework, though qualifying his comments by suggesting that failure was not due to insufficient power or surface, but to not knowing how to combine the two.

In his letter of September 22nd 1868, Brearey commented on the weight of this model in relation to its surface, as he did in the extract from his 1869 paper already quoted. Brearey's letters to Stringfellow all indicate he was trying to pin the latter down to details, as, indeed, doubtless Stringfellow was trying to remember them. *Reference* (p. 373) *has been made to Stringfellow's important letter of September 21, 1868. In it he refers to his work with Henson, as follows:*

" If Henson and me generally took the Rook as our standard as carrying 1 lb. to a foot, this bird can be seen any day leisurely flying at a speed not more than 20 miles an hour, and we considered if we kept our machine within these limits we had a fair chance of success. I am apprehensive we shall find our shortcoming not because we have too much or too little sustaining surface either. There must be a wide margin. The difficulty is to make the full power of the engine available. This I do not think we have ever done with the present arrangements and proportion of our propellers."

Although Stringfellow suggests here that, following the rook 1 lb. per sq. ft. appeared a suitable wing loading, the models made had loadings of only 1/3 or ½ lb. per sq. ft.

Johnston, in his account of Henson, suggests that he and Stringfellow parted on bad terms. " There are hints in the family records of a violent quarrel with Stringfellow. When it occurred and over what issues are still unknown, but Henson's opinion of Stringfellow in his later years made such an impression upon several of his children and grandchildren that two generations later it is clearly remembered that the name of ' Stringfellow ' was forbidden in the Henson household and that William Samuel took frequent occasion to denounce his former partner as one who had robbed him of his ideas and who had taken credit for them."

This requires investigating more closely. " Henson's opinion of Stringfellow *in his later years . . . .*" says Johnston. One wonders if Henson's opinion became more strongly expressed following the reports of the Aeronautical Exhibition of 1868, when Stringfellow got all the glory of winning the £100 prize for a light engine, and exhibiting a steam engine driven model running along a wire for Royalty to admire?

Stringfellow's letter betrays nothing about any quarrel. Quite the reverse, in fact. Yet there remains the fact that the obituaries in the local papers omit all reference to any work with Henson, and give Stringfellow alone the credit. Evidently something went wrong, but there does not seem to be any definite evidence what it was.

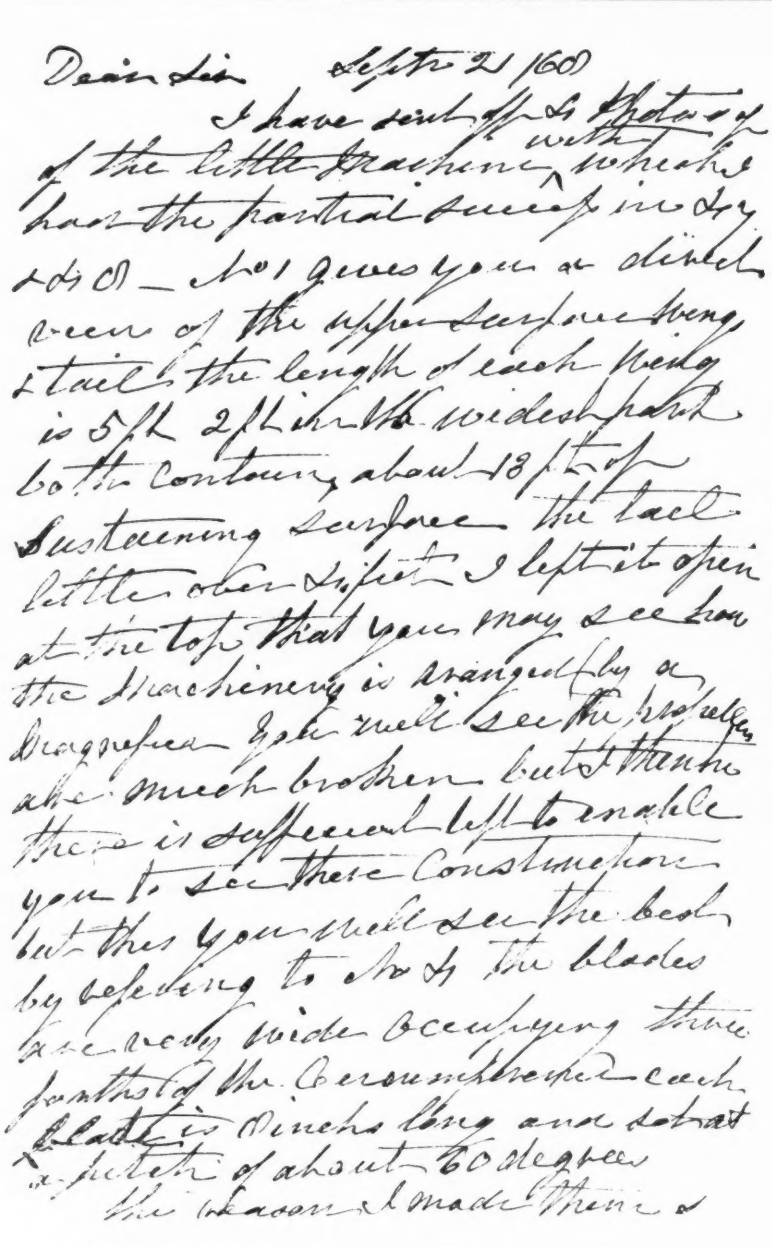
There is one thing which may shed a light on the position round about that time, and that was the question of money. Henson had come to Chard, while his father had gone to America, to build up the lace-making business. Henson was in his twenties and Stringfellow some twelve years older.

From 1841 to 1846 both men had given considerable time to the building of models and engines and experimenting with various forms of construction, and their businesses must have suffered to some extent. It is more than likely that Henson senior, in America, was not too happy about his son in Chard, from a business point of view. Stringfellow must have been reasonably well established. His obituary notice recorded that he bought the row of houses in 1833 in which his own house stood.

On the question of finance it should be remembered that on September 28, 1846, Henson wrote to Sir George Cayley,

" Although I am personally unknown to you I have taken the liberty of addressing you this letter upon Aerial Navigation knowing it to be a subject in which you as well as myself feel deeply interested. You probably imagined that I had long since given it up as a failure, and you will no doubt be pleased to hear that I have in conjunction with my Friend Mr. Stringfellow been doing more or less ever since 1843 towards the accomplishment of Aerial Navigation and that we feel very sanguine as to the result of our endeavour and consider that we have arrived at that stage of proceedings which justifies us in obtaining that pecuniary assistance necessary to carry on our efforts upon an enlarged scale and with increasing energy. We therefore resolved to apply to you as the Father of Aerial Navigation to ascertain whether you would like to have anything to do with the matter or not. We have conducted our experiments in a strictly private manner and trust you will consider this communication the same. We find steam power ample for our purpose but of course we should not confine ourselves to it if your Air Engine offers superior advantages."

Cayley replied, " . . . . . I had thought that you had abandoned the subject, which though true in principle, you had rushed upon with far too great confidence as to its practice some years ago. If you have been making experiments since that time you will have found how many difficulties you have to adjust and overcome before the results you wish can be accomplished. I think that Balloon Aerial Navigation can be done readily and will probably in the order of things come into use before mechanical flight can be rendered sufficiently safe and efficient for ordinary use. I like your zeal, and as you seem disposed to treat me with your confidence I can only assure you that I shall not abuse it. As to new principles, there are none, of practical expedients there will soon be an endless variety and to select the best is the point at issue. I hope to be in Hertford Street (No. 20) the latter end of



The first page of Stringfellow's letter to Brearey about the 1848 model, which reads:—

To F. W. Brearey Esq.

Sept 21 1868

Dear Sir

I have sent off 4 photos of the little machine with which I had the partial success in 47 and 48—No. 1 gives you a direct view of the upper surface wing and tail the length of each wing is 5 ft, 2 ft in the widest part both contain about 13 ft of sustaining surface the tail little over 4 ft. I left it open at the top that you may see how the machinery is arranged by a magnifier You will see the propellers are much broken but I think there is sufficient left to enable you to see their construction but this you will see the best by referring to No. 4 the blades are very wide occupying three fourths of the circumference. Each blade is 8 inches long and set at a pitch of about 60 degrees.

The reason I made them—

(*See also* text.)

November or beginning of December, when if you can show me any experimental proof of mechanical flight maintainable for a sufficient time by mechanical power, I shall be much gratified, and though I have not the weight of capital to apply to such matters, I perhaps might be able to aid you in some measure by my experience or connexion with other mechanical persons. I do not however, think that any *money*, excepting by exhibition of a novelty can be made by it."

Whether Henson was discouraged by Cayley's last comment, or whether he was not able to give Cayley any experimental proof " of mechanical flight maintainable for a sufficient time by mechanical power," is not known. There certainly appears no evidence that Cayley had any further communication with Henson, but the letter does make it clear that Henson was looking round for finance to carry on his experiments.

Stringfellow must also have been well aware of Henson's letter and Cayley's comments on Henson's Aerial Steam Carriage in the *Mechanics' Magazine* for April 8, 1843. There Cayley had drawn attention to the difficulty of building cantilever aeroplane wings of the span Henson's project demanded.

" In order to obtain a sufficient quantity of surface to sustain great weights in the air, the extension ought not to be made in one plane but in parallel planes one above the other . . . . would it not be more likely to

answer the purpose to compact it in the form of a three decker? "

It was a three decker which Stringfellow made for the Aeronautical Exhibition at the Crystal Palace in 1868, the only design in which it is certain Henson had no hand, and for which no claim was made that it had made a free flight.

In the accounts by Brearey and F. J. Stringfellow of the model experiments of 1844-47, no claim is made that any model flew, nor was any claim put forward by Stringfellow himself. (But *see* page 387).

7. Stringfellow's Experiments 1848

In January 1869 Brearey wrote, after describing the failures on Bala Down, " In 1846 he (Stringfellow) commenced a smaller model for indoor trial, and, although very imperfect, it was the most successful of his attempts."

This is written as though Henson has already broken away from Stringfellow, whereas, in September that year, he had been in communication with Sir George Cayley, had referred to his friend Mr. Stringfellow, and used the words " We therefore resolved to apply to you . . . . ." This year is an important one. The two men had been working together for at least four years and must have known each other's outlook pretty well, and each other's ideas. Even if Henson had left Stringfellow at the end of 1846 (and there is no evidence to that effect), the latter must have learnt a lot of Henson's methods of construction, as both men must have found out the difficulty of handling the large model with which they had been experimenting.

The new model, which Brearey states was begun in 1846, was only half the span of the earlier one and its detailed construction bears many indications of Henson's influence, as well as original ideas by Stringfellow, particularly that of launching the model along a wire.

In reply to Brearey's request for photographs and some description of his machine, Stringfellow wrote on September 21, 1868,

" I have sent off 4 photos of the little machine with which I had partial success in 47 and 48. No. 1 gives you a direct view of the upper surface wing and tail. The length of each wing is 5 ft., 2 ft. in the widest part, both contain about 13 ft. of sustaining surface, the tail little over 4 ft."

Brearey gives the total area as 17 sq. ft. which fits in with Stringfellow's letter and " The weight of the entire model and engine as six pounds, and with water and fuel it did not exceed 6 and a half pounds."

F. J. Stringfellow, twenty-three years after Brearey, gives the weight as being " under nine pounds " and the area of the wings and tail as 14 sq. ft.

Davy accepts these figures as against Brearey's, saying " It may be assumed that the information contained in these accounts were derived from a common source, i.e. the notes and memoranda which Stringfellow himself made while the experiments were in progress. The notes are known to have been in the possession of his son, so that F. J. Stringfellow's account should have the prior claim to acceptance where any discrepancy occurs."

The notes appear to have been lost.

Davy's statement is at least open to discussion. Brearey definitely had the area given to him twenty-one years earlier than F. J. Stringfellow wrote, from John Stringfellow himself. Brearey was a man who took considerable care over details, as many of his letters testify. The figure of 17 sq. ft. in the Memoir of 1883 is that of the article of 1869, and it seems likely that Stringfellow would have told Brearey if it had been incorrect, for the two men were meeting and corresponding in 1869 and for many years after.

Davy himself writes, when discussing the reconstruction, " F. J. Stringfellow, as already noted, gave the area as being 14 sq. ft., but Brearey stated that the wings ' contained seventeen sq. feet; ' actually the total wing and tail area, as calculated from measurements of the original parts, is 18,028 sq. ft."

The figures are against F. J. Stringfellow being correct, for actual measurement indicates that the figure given by his father to Brearey was much nearer the truth. It is odd that Davy, six years later, in his *Interpretive History of Flight*[23], abandons both Brearey and F. J. Stringfellow, and gives the total area as about 18 sq. ft. He chooses F. J. Stringfellow's weight, however, in preference to Brearey's and adds, " The loading, if the tail is included, was thus 0.5 lb. per sq. ft., i.e. the loading proposed by Henson."

On Brearey's figures the wing loading is about 0.4 lb. per sq. ft., and on Stringfellow's 0.6, a considerable variation.

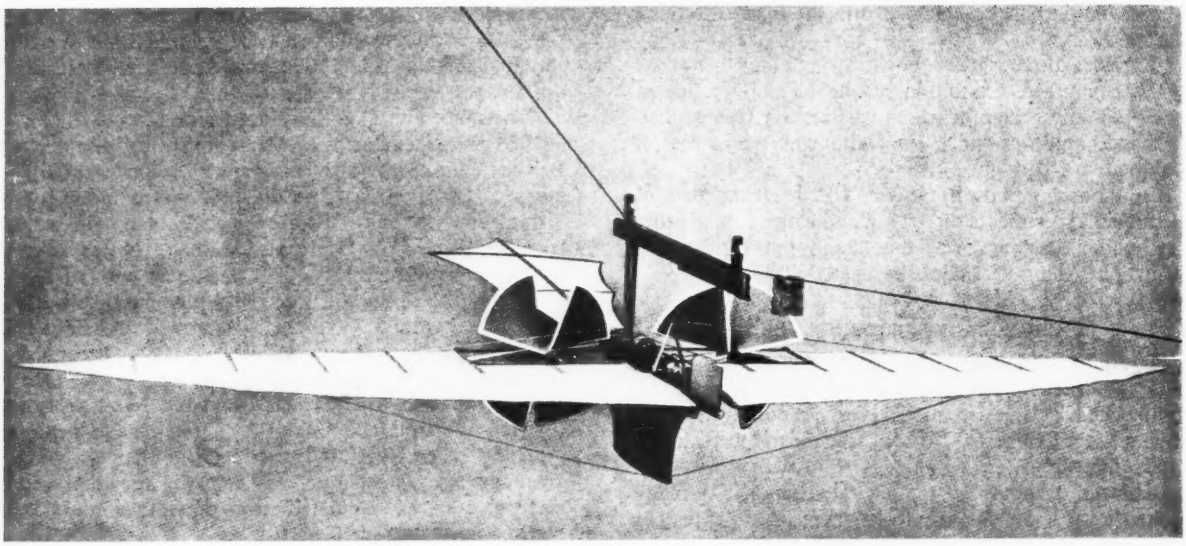
The Science Museum's account[22] gives a detailed description of the model, which was reconstructed. The greater part of the model, wings, tail, propellers, engine and boiler still existed, but were in a very dilapidated state, at the time of the death of F. J. Stringfellow. Both the 1844/47 Henson-Stringfellow model relics and those of the 1848 Stringfellow model, were acquired by C. H. M. A. Alderson and P. Y. Alexander, two members of the Society, who generously presented them to the Museum in 1907/8 on behalf of the Society.*

**It was reported at the Council Meeting of December 15, 1905, that a letter had been received from C. H. M. Alderson saying that the family of the late F. J. Stringfellow were willing to part with the Stringfellow collection of models and suggesting that they might be acquired by the South Kensington Museum.*

At the March 19, 1906 Council Meeting it was reported that a letter had been received from P. Y. Alexander (a wonderful friend of the Society over many years) that he had bought the 1848 Stringfellow model and would like to present it to the British Museum as from himself and Mr. Alderson, through the Aeronautical Society.

The following month Alderson gave the Council a detailed description of the Stringfellow relics, their dilapidated condition, and proposals for their restoration.

The Science Museum and the Society owe an immense debt to Patrick Alexander and C. H. M. Alderson for their generosity and for the care they took to preserve these relics. Out of twelve relics of Henson and Stringfellow listed in the Science Museum Handbook on the life and work of the two men, no fewer than eight are acknowledged to Alexander's and Alderson's generosity and help.



Courtesy of the Director of the Science Museum

Stringfellow's 1848 model (reconstructed) showing launching method.

The 1848 model was in such a bad condition that a reproduction was made—though not until 1926. The engine had been taken out of the model and used for some years to drive a small lace machine in Taunton. It was given to the Museum by Sir John H. Amory, in whose factory the engine—partly modified, probably by Stringfellow himself—had done good service. Certain parts of the engine are missing, as were certain parts of the structure of the model.

Davy's detailed description of the model states, "The wings, or main supporting surfaces, are constructed fundamentally on Henson's plan in that they are built upon transverse spars (in this case the spars are two in number) to which the ribs determining the wing shape are attached. Contrary, however, to Henson's design, that portion of the wing behind the rear spar is to some extent flexible."

Davy asserts that this form of construction has been repeatedly suggested by writers on the problem of flight, that it assisted in the maintenance of stability, and that Stringfellow was the first to apply it in an actual model.

The wing section was much flatter than that of Henson's original idea of 1842.

"Each of the wings is supplied with small fittings on its main spar which must have been intended for the attachment of what were known latterly as "flying" and "landing" wires, there being no other provision for the necessary external bracing of the wings," writes Davy. "The use of such bracing wires necessitates some central point of attachment above the wings and below them. The attachment beneath is made, obviously, in the bottom of the car, but the point of attachment above is less apparent as there is no indication in the original, or in contemporary photographs, of any structure which might serve the purpose. The evidence for the provision of 'landing' wires is conclusive, but there is no evidence as to what they were attached to when passing above the wings. A solution was suggested by the introduction of a simple inverted V-shaped member above the body, and this has been adopted in the reproduction . . . . ."

Why the inverted V shape was suggested is not known, for there were no obvious places for the fixing of the feet of such a bracing member. That it is a simple way of doing the job will not be disputed, but that it was the actual way is not known. Davy himself, in his book on the *Interpretive History of Flight*, published in 1937, writes of the wings "they were braced above from a central post in the body." ! !

". . . . The propellers were sixteen inches in diameter," wrote Brearey in 1869, "with four blades occupying three fourths of the area of circumference, set at an angle of sixty degrees."

Stringfellow, in his letter of September 21 1868, added,

"The reason I made them so wide, at the time I had an impression, right or wrong, that a wider blade would be required in a medium as yielding as air."

To Stringfellow must be given the credit of designing a method of launching the model. Henson had advocated in his patent, "In starting the machine, I prefer to do so from an inclined plane or the side of a hill, and I allow the machine to run forward down the incline, the propellers being first set in motion, when it will be found that in a short time they will act sufficiently upon the air to cause the machine to leave the incline and proceed in any desired direction."

This method had been tried unsuccessfully on Bala Down, out in the open air. Stringfellow concentrated

on indoor testing, where there were no currents to upset the model, for he certainly did not seem to have grasped the stability problems involved, if a current of air should strike his model in flight. Control really never entered into the experiments of the two men, in the same way as it does now, an important thing to remember.

This 1848 model was intended to fly in a straight line. It had no rudder, relying upon the keel surface provided by the engine casing. The tail was adjustable, and this again followed Henson's 1842 ideas. To quote the Patent, "I apply a tail to the extended surface, which is capable of being inclined or raised, so that when the power is acting to propel the machine, by inclining the tail upwards, the resistance offered by the air will cause the machine to rise on the air; and, on the contrary, when the inclination of the tail is reversed, the machine will be immediately propelled downwards . ."*

Stringfellow adopted this suggestion in full, so that he could adjust the tail for each trial. He also adopted the inclined plane in a different form. His model was suspended from a small apparatus running on grooved wheels along a wire. An automatic release at any pre-arranged point along the wire, freed the model in flying attitude.

Davy describes the method of release as follows:

"Steam having been generated and the model restrained until the propellers had reached a maximum speed, it was released and allowed to travel along the wire (which was inclined slightly downwards) until the lower members of the launching apparatus encountered a block fixed on the wire and was pushed back with the steel pin, thereby releasing the loop and freeing the model in front, its inertia serving to draw it from the rear support and to launch it in free flight.

"The position of the block fixed on the wire (the point of self detachment)was determined by experiment, and it was so found, in one particular case, that a run of about twenty-two feet was sufficient to enable the model to attain, from the combined thrust of the propellers and the slight assistance of gravity, the speed necessary to render it self-supporting."

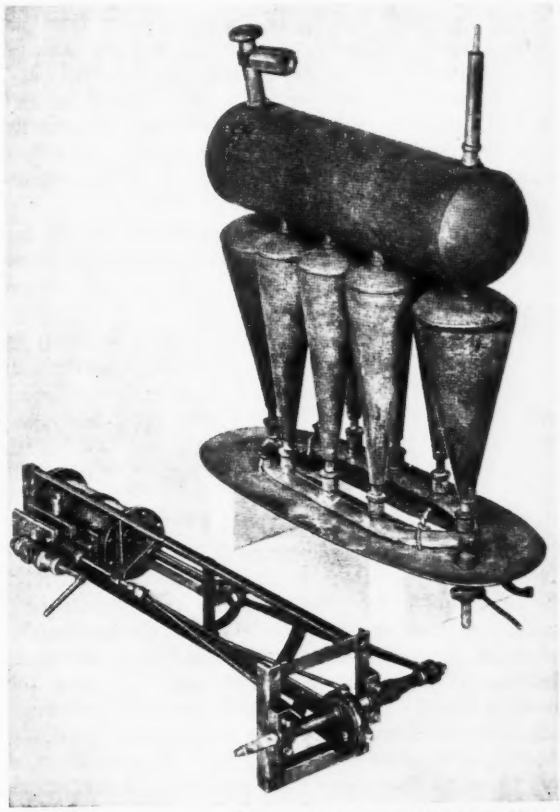
In a letter dated August 15, 1903 to C.H.M.A. Alderson, F. J. Stringfellow wrote "the manner of trying the model was very easy, but it was advisable to stretch a piece of canvas under the proposed point of liberation so that if the model was launched prematurely it would not be damaged."

Before commenting on the method of launching, the full description of these 1848 experiments as given by Brearey and F. J. Stringfellow may be noted. The latter's account enters into more detail than does Brearey's, otherwise the two accounts are substantially the same.

"My father had constructed another small model which was finished early in 1848, and having the loan of a long room in a disused lace factory, early in June the small model was moved there for experiments. The room was about 22 yards long and from 10 to 12 feet high . . . . . The inclined wire for starting the machine occupied less than half the length of the room and left space at the end for the machine to clear the floor.

"In the first experiment the tail was set at too high an angle, and the machine rose too rapidly on leaving the wire. After going a few yards it slid back as if coming down an inclined plane at such an angle that the point of the tail struck the ground and was broken. The tail was repaired and set at a smaller angle. The steam was again got up, and the machine started down the wire, and, upon reaching the point of self detachment, it gradually rose until it reached the farther end of the room, striking a hole in the canvas placed to stop it.

"In experiments the machine flew well, when rising as much as one in seven. The late J. Riste, Esq., lace manufacturer, Northcote Spicer, Esq., J. Toms, Esq. and others witnessed the experiments. Mr. Marriatt (misspelling for Marriott), late of the *San Francisco News Letter*, brought down from London Mr. Ellis, the then lessee of Cremorne Gardens, Mr. Partridge, and Lieutenant Gale, the aeronaut, to witness experiments. Mr. Ellis offered to construct a covered way at Cremorne, for experiments. Mr. Stringfellow repaired



Courtesy of the Director of the Science Museum

Engine and boiler of Stringfellow's 1848 model.

*Neither Henson or Stringfellow appear to have been aware that climb depends on engine power.

to Cremorne, but not much better accomodations than he had at home were provided, owing to unfulfilled engagement as to room.

"Mr. Stringfellow was preparing for departure when a party of gentlemen unconnected with the Gardens begged to see an experiment, and finding them able to appreciate his endeavours, he got up steam and started the model down the wire. When it arrived at the spot where it should leave the wire it appeared to meet with some obstruction, and threatened to come to the ground, but it soon recovered itself and darted off in as fair a flight as was possible to make a distance of about 40 yards, where it was stopped by the canvas.

"Having now demonstrated the practicability of making a steam engine fly, and finding nothing but a pecuniary loss and little honour, this experimenter rested for a long time, satisfied with what he had effected. The subject, however, had to him special charms, and he still contemplated the renewal of his experiments."

This statement is as precise as it is vague. It is precise in the things which do not matter greatly, as the length and height of the room at Chard, and in the names of witnesses, but vague as to the actual point at which the model left the wire, the inclination of the wire down which the model ran, or exactly how far away the canvas, placed to receive it was. The engine power is never stated, nor the revolutions per minute of the propellers nor the setting of the tail plane.

Some notes of Stringfellow's are extant, and they are detailed and such as one would expect from an experimenter who knows what he is doing and what he is after. But the notes refer to engine experiments only, and engines were his speciality long before he met Henson, and remained so all his life. Davy very rightly drew attention to this and wrote "His reputation is thus based principally upon his construction of light steam engines."

Of recorded notes for the model tests on similar lines as those for the engines, giving length of flight, speed, path of flight and so on, there do not appear to be any.

The account published by the Science Museum of the method of launching, already quoted, gives a run of twenty-two feet, *in one particular case*, as being sufficient to enable the model to attain, from the combined thrust of the propellers and the slight assistance of *gravity*, the speed necessary to render it self-supporting.

Now the length of the model is 7 feet[22]. Assuming that the starting point was about a foot from the end of the wall, and the canvas to catch the model was about the same distance from the other wall, the flight finishing as soon as the nose of the model struck the canvas, the whole of the flight path would be less than five times the length of the model. Davy estimates that the distance must have been some 40 ft. but a little reflection will show that this must be an over-estimate. No doubt the example chosen was the most favourable, and the point of free flight was past the 22 feet mark normally, so lessening the actual distance the model was on its own.

It should be remembered that its initial speed was greater than that obtained under its own power, for it had the "slight assistance of gravity."

The model had its tail plane set so that the attitude of the model as a whole would, to the uninitiated, give the appearance it was climbing. It was lightly loaded, and given the initial kick off it would have glided five times its own length without much, if any loss of height. Very little extra thrust would cause it to rise to some extent in that short distance, but on the evidence it is difficult to be sure that the model was climbing under its own power, in the aeronautical sense.

Octave Chanute, whose qualifications for assessing the value of aeronautical experiments are high, wrote in his book *Progress in Flying Machines*[16], after reading Brearey's descriptions of Stringfellow's experiments,

". . . . . the equilibrium was still insufficient for experiment out of doors, and the important problem of safely coming down was not solved at all, for to prevent breakage the apparatus had to be caught in a canvas fixed to receive it . . . To mitigate this difficulty Mr. Stringfellow increased the sustaining surface so that it was 2.61 sq. ft. per pound, and therefore might act like a parachute, but this largely increased the 'drift' and required more power, so that water and fuel could only be provided for a very brief flight, and the machine cannot fairly be said to have 'demonstrated the practicability of making a steam engine fly'" (quoting Brearey's words).

The Cremorne account immediately follows that of the experiments at Chard. The first thing to notice about it is the identity of one of the witnesses, Frederick Marriott. He it was who brought down from London 'Mr. Ellis, the then lessee of Cremorne Gardens' to witness Stringfellow's experiments. Marriott was the same Marriott who had been concerned with promoting the Henson project of 1842. He was at one time a resident of Chard and it was through him that the fierce blaze of publicity burst over Henson in 1843. He was a journalist who was extremely interested in the possibility of flight, an interest he never lost all his life[20].

Marriott was a member of the Aeronautical Society and went to San Francisco in 1848, where he settled to become the editor of the *San Francisco News Letter. Copies of this he sent to Brearey, who made extracts from it for use in the Annual Reports of the Society.* Marriott patented a dirigible with lifting planes in 1869, and a brief description appears in the *Annual Report* for 1875.

Brearey used to send his copies of the News Letter to Stringfellow occasionally. In one letter, dated June 15, 1870 Brearey said "I wrote to Marriott, and in return I received the enclosed but no letter. I expect he did not want to say anything about you." In a second letter to Stringfellow, dated July 5, 1870, he wrote "I send you two numbers of the NEWS LETTER *which you need not return. Marriott has not replied to me . . . .Who is that Henson that advertises as a Civil Engineer in the* NEWS LETTER?"

Johnston records that Henson classed himself in the Newark Directory in America at times as a 'civil engineer' but Johnston adds 'There is nothing to indicate that Henson was ever in touch with his former colleagues.'

Perhaps this odd reference might alter that slightly.

This digression on Marriott is important in what happened at Cremorne. He had got Stringfellow there, and, as a journalist, and one keenly interested in flying news, and one who had seen Stringfellow's early work with Henson and by himself, he would not let anything slip in the form of a story.

There has always been an air of vagueness about Cremorne. Some of this vagueness was unnecessary. Davy refers to an undated cutting, "probably early in August 1848". A search would have found the date and the paper without much difficulty. THE ILLUSTRATED LONDON NEWS *carried advertisements of London Amusements, including those of Cremorne. F. J. Stringfellow, in his own copy of Brearey's 1869 paper, had written in the incorrect date as September 1848. A search through the files for that month revealed nothing but there appeared in the issue dated Saturday August 12, under Cremorne, "Aerial Steam Navigation. The Lessee has the honour to announce he has concluded arrangements for an Exhibition of Models, worked by steam power, without the aid of gas, and illustrative of this new scientific movement of the age."*

This is the wording of Davy's undated newspaper cutting.

In the issue dated Saturday August 19, 1848 appeared the following,

"Cremorne. Aerial Steam Navigation and Balloon Night Ascent. On Monday August 21st. Lieut. Gale will make another night ascent, at 10 o'clock, and discharge from the car a magnificent display of fireworks. Flights of the Aerial Carriages between three and six o'clock; previous to each a brief explanatory lecture will be delivered . . ."

There was no further mention of the Aerial Carriage in previous or following issues of the ILLUSTRATED LONDON NEWS *in which the Cremorne advertisements continued to appear, so it looks as though the attraction only lasted a week, if as long as that.*

In *The Times* dated Tuesday August 22, 1848, appeared a paragraph which is given in full, for its bearing on the Cremorne story, as told by Brearey and F. J. Stringfellow. Davy quoted from this report of *The Times*, but left out all the words italicised, giving a misleading impression of what happened at Cremorne.

"The Aerial Machine.

"A series of experiments were made beneath an immense hood or awning in Cremorne Gardens yesterday afternoon to test the powers of a machine invented by Mr. Stringfellow to maintain and propel itself through the air. The day was most unpropitious and it would be hardly fair to pass judgment on the powers of the machine to carry out the assertions of the inventor, as those who have witnessed it under more favourable circumstances. It certainly possesses a propelling power *and it would appear that with the addition of a sustaining power it might form an important aid to aerial or balloon experiments.*

"A great many scientific gentlemen and others connected with inventions were present. The attempts will be repeated to-morrow and as the thing is of rather more than ordinary interest, the friends of science have an opportunity of forming their own judgment of its worth."

This notice is interesting and significant, most especially the last paragraph. The very people, "scientific gentlemen and others connected with inventions" were present, who were better able to judge than the non-technical people. The same kind of people, twenty years later, were present when Stringfellow demonstrated his triplane at the Crystal Palace. And upon them the impact of Stringfellow's aeroplane model appears to have been very similar—*i.e.* it caused no 'follow up' interest.

The Times report, which appears to be the only one made of *Stringfellow's visit to Cremorne, was quite clear that the experiments made that Monday afternoon were not successful.*

Marriott would have been as disappointed as the rest, as he had brought Stringfellow to Cremorne. And undoubtedly, as a journalist, he would have jumped at any success about which he could write and justify his interest in Stringfellow. The paragraph in THE TIMES *might well have been inspired by him.*

The last sentence reads "The attempts will be repeated tomorrow and as the thing is rather more than ordinary interest, the friends of science have an opportunity of forming their own judgment of its worth."

That judgment has not been found, if it was ever recorded. A flight of 120 feet of a model steam engined heavier-than-air craft was something, "a thing of rather more than ordinary interest", to repeat the following day and many times afterwards. But save for that brief and rather damning notice in THE TIMES *nothing more is known of the Cremorne experiments. It doesn't make sense that Stringfellow would not have told Marriott about the 40 yards flight, if he had not been present, and that Marriott would not have seized on it as something worth writing about and urging interest in, for he was strongly biased on the possibility of flight. Especially as Stringfellow had gone to California with Marriott, shortly after the Cremorne experiments, in 1848*[5].

In those few weeks of 1848 Stringfellow was claimed by Brearey and his son to have made a number of flights, two of them outstanding, and none reported at the time. Immediately after these triumphs "this experimenter rested for a long time, satisfied with what he had effected," to use Brearey's words of 1869, meticulously copied by F. J. Stringfellow, word for word, in 1892. Odd, isn't it, that the son refers in the same paper to "my father" and to "this experimenter"?

Of F. J. Stringfellow's account Davy wrote, "It is brief and prosaic, scarcely rising to the enthusiasms which the subject would seem to warrant, but it must be borne in mind that his pamphlet was published forty-four years after the events described. In default of any further progress having been made, they would naturally have fallen into comparative obscurity even within the circle of Stringfellow's family."

Much of the tenor of the writing of the Science Museum's account betrays an uneasy feeling about the whole matter.

"The question of the authenticity of the performance as just recorded may quite possibly arise in the mind of the reader: of the three witnesses named only two were, it seems, living when the account was published in 1892, i.e. Mr. Northcote Spicer and Mr. J. Toms. From some correspondence which took place in 1903 it appears that, at that time, none of the original witnesses were living. . . . . The evidence contained in F. J. Stringfellow's pamphlet was, it seems, accepted without any corroboration by such contemporary writers as Octave Chanute in America and by others, and it had been accepted by subsequent writers and historians as an accurate description of the experiments."

It will be remembered that Chanute's judgment was that the machine could not fairly be said to have demonstrated the practicability of making a steam engine fly.

Davy records that "A careful search in the files of the local press has not revealed any reference to these experiments." Nor, outside Brearey's Memoir of 1883 was there any account of any kind given or mention made of Stringfellow's visit to Cremorne or experiments with Henson and himself in Chard in the *Annual Reports* of the Society.

Both Spicer and Toms might have added something to F. J. Stringfellow's account, though 44 years later, but did not do so. *For Davy to say the account was accepted without any corroboration by Chanute and by subsequent writers and historians as an accurate description means only as Paul Johnston put it in his paper on Henson that "aeronautical historians have been either inept or downright lazy."*

The obituary notice in the CHARD AND ILMINSTER NEWS *of December 22, 1883, mentioned the abortive experiments on Bewley (Bala) Down, but said nothing at all of the flight in the disused lace factory, or of that at Cremorne ". . . . . though his ideal can scarcely be said to have been fully realised, yet to him, we believe, the credit and satisfaction belong of having more nearly attained to it than, perhaps, any other among the many eminent men in England and on the Continent to whom this has also been a life study.*

"The highest testimony to this effect is the fact that in 1868, at a grand competition arranged by the Aeronautical Society at the Crystal Palace, the highest prize of £100 was awarded to Mr. Stringfellow for his machine as being the best exhibited."

The plain fact is that he received no prize at all for "his machine" but one for the lightest engine for its power, an engine not made for an aeroplane model, and one which was not actually tested as to horsepower, but calculated.

From August 1848 until 1867 there is no evidence that Stringfellow carried out any more model experiments. In fact the engine of his 1848 model was altered and used in a lace-making factory in Taunton, as already noted.

It has been noted and commented upon, that Brearey's account written in the autumn of 1868 and published in January 1869 of the 1848 experiments and flights, was largely supplied by Stringfellow himself, and therefore accepted as being accurate.

Yet only six years later, in a letter dated January 30, 1875, Brearey wrote a letter to the DAILY TELEGRAPH *which began:*

"The time, I think, is coming when the public interest in aeronautical efforts is likely to be intensified. Its students have been quietly marching to the front these nine or ten years past. One day they will take the world by surprise . . . . ." . .

Brearey discusses the pros and cons of lighter and heavier-than-air methods, and of the experimenter in the latter form of flight he says,

"He possesses much encouragement from the various flying machines which have been for ages the constant source of his observation and study. It is no discouragement to him that those flying examples—the birds—are possessed of vitality which he cannot hope to imitate. He sees only in those living prototypes a mechanical action, which he declares that he will one day appropriate and convert to social and commercial purposes. He makes models which will fly, albeit generally upon too small a scale to carry their own motors—though, as a matter of fact, one of Mr. Stringfellow's earlier models is stated to have flown with its steam engine and boiler."

It is significant that Brearey in his 1869 account did not use the words "it is stated", but accepted Stringfellow's comments *in toto.*

Brearey had been in close touch with Stringfellow since the early part of 1868, writing to him often, and had visited him and talked with him at great length. On April 22nd 1875, for example, he wrote a letter beginning "My dear friend," giving an account of Thomas Moy's experiments at the Crystal Palace. Brearey added that he had been in a railway accident and had to be in bed for a month with injured knees. The same year, on September 8, 1875., "Let me know what time your train arrives at Waterloo so that I may be able . . . to meet you . . . We have got bed and board for you in the house, small as it is, and a hearty welcome."

It seems pretty clear that Brearey, after six years acquaintance with Stringfellow and seeing his models and engines, did not attach anything like the importance to the experiments of 1848 which time has given to them. *Brearey's letter to the* DAILY TELEGRAPH *was to boost Aerial Navigation and the Aeronautical Society, about whose work over the first ten years he enthuses,*

particularly that of Thomas Moy. His letter is a long one. "Space is wanting to describe other but more tentative efforts which are in making by other members of the Aeronautical Society," he wrote after describing Moy's experiments.

John Stringfellow was a member, but all that could be said about him by his friend Brearey was "it is stated" of the experiments of 1848.

Before leaving this section it is of interest to draw attention to a letter written by John Stringfellow to Brearey, dated September 21, 1868. In it he wrote, *"The bat wing model of which I first sent you photograph you do not name—this I consider more perfect than the one I had at Cremorne but I was not able to try it for want of a room. In my opinion it would have made the best plate."*

This letter was one in reply to the one by Brearey asking for information for the purposes of writing his article for the *Popular Science Review*, published in January 1869. The extract is interesting as revealing that Stringfellow had got a model "more perfect" than his 1848 Cremorne model, "but I was not able to try it for want of a room."

Yet with the £100 prize he had won at the Crystal Palace Exhibition a few months before, he built a long room at Chard for experimental purposes, so that he had every opportunity of trying out his new model "more perfect" than the 1848 one said to have made a free flight of 120 feet.

If any experiments were carried out, no records appear to have been kept.

8. Stringfellow and the 1868 Aeronautical Exhibition

On October 14 1867 Brearey wrote to Stringfellow, "I enclose you a circular of our proposed Exhibition, as I hear you might perhaps have something to exhibit."

On November 21, 1867, Brearey, replying to a letter from Stringfellow, wrote, "I was very glad to receive your letter this morning. I quite agree with you that if you have succeeded in making a flying model you have solved a problem under discouraging circumstances. The next thing to do is to convince the world of it and no better opportunity exists for attracting general attention than the coming exhibition . . . . . "

On December 18, 1867 Brearey wrote, "I am very much obliged for your interesting letter and photos which I shall read and show at our Council meeting on Thursday. It is a great pity that experience like yours should be lost to the world, but I think that you see that the time has arrived when publicity may be given to your attempts. So far as I can see you would secure the prize to be given for the best working model, always supposing that it would maintain flight for the distance you state, 40 or 50 yards. I have yet to examine more closely with a magnifier, your photos. Does the machine carry its own motor?"

These photographs must have been of the 1848 model. From the letter it would appear that Brearey knew nothing about it and had not been down to Chard to see the model. The engine was missing, as already recorded. Stringfellow had evidently referred to the experiments at Cremorne, and to the 40 yards. Yet the machine or a replica of it, with such an outstanding success behind it, was not entered for the Exhibition or discussed by the members of the Society during the three meetings held at the time of the Exhibition! Nor did Stringfellow say anything more than that "It flew—in 1847." He gave no description of it, or where it flew, and put the date wrong by a year. Here, indeed, was the grand opportunity to "convince the world of it!", an opportunity missed.

In his letter of November 21, 1867 to Stringfellow, Brearey finished with the words, "I wish you could give me a full description of the performance of your model. I think I would publish it in our next Annual Report now compiling."

The next Annual Report, as with all the Annual Reports during Stringfellow's lifetime, is silent on the subject.

Stringfellow replied to Brearey's letter four days later, on November 25, 1867, but avoided giving the "full description of the performance" of the model for which Brearey had asked.

". . . . The principle I have been working on is very simple. I have adhered to the Bird as near as possible merely substituting the wheel as the propeller or driver keeping the wing rigid as a sustaining surface. I hope to look up some of my things and try if I can put a model in something like ship-shape, but unfortunately I have not sufficient length barn to experiment in, having let the premises in which I formerly carried on my experiments."

"I have often thought that they might have got up a working model at the Crystal Palace that would have attracted some attention without very much expense but small working models require to be made very nice (sic). All the flights have been made in a long room, still atmosphere. Perhaps something might be done in large models by shortening the wing and placing one tier a little distance above the other. Still it would have its drawbacks and of no assistance, I think, in small models. I will try and send you a photo of the model or parts as soon as I can manage to do so."

It is clear from this part of his letter that Stringfellow not only had no model ready, but that his 1848 model had been broken down, and that he was thinking of making a multiplane, though a little doubtful as to the result.

Only a few weeks before the Aeronautical Exhibition was due to open, *Stringfellow wrote, on June 4, 1868, to Brearey, "It would be desirable to know positively if the model could be exhibited in the interior. I should wish to know the length and height of the building clear of everything. I shall make it go from one end to the other* BY SOME MEANS *. . . . The machinery and things*

generally work very well, but I'm not certain the sustaining planes are the best possible arrangement."

Evidently Brearey was not clear what Stringfellow meant in his letter, for on June 10th. the latter wrote again, "I am sorry if I have said anything to mislead you. In the letter you refer to I stated I would make it go from one end to the other of the building BY SOME MEANS. *This can be done by a guide line and certainly in the 1st experiments I should not attempt to liberate it till it had thoroughly proved capable of self-control. Whatever shortcomings there may be at 1st, there is nothing in the principle but what may eventually be surmounted . . . . There is no room sufficiently large for experimenting in the neighbourhood (i.e. Chard) or I should not have kept my old models rotting for years."*

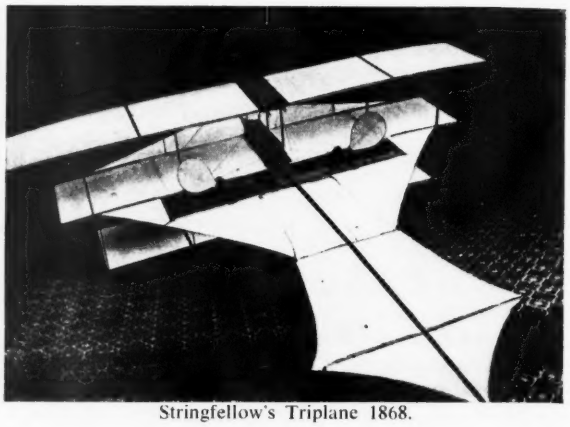
It still remains puzzling why he did not continue on the lines which had apparently been so successful. As it was, he abandoned certain features of his 1848 model as a flexible trailing edge and monoplane construction, in the construction of the triplane. No detailed description of the triplane was published at the time. The Science Museum gives the wing area as 28 sq. ft. and total weight as 12 lb. Chanute adds 8 sq. ft. for the tail, making 36 sq. ft. in all, giving a wing loading $\frac{1}{3}$ lb. to the sq. ft., "which was certainly ample for support." The engine is said to have developed a third of a horsepower, but its weight was not stated. Like the earlier model of 1848, the triplane was suspended from an apparatus running along a wire on grooved wheels, but with no release mechanism as the Crystal Palace authorities forbade free flights.

Brearey had asked Stringfellow, in his letter of December 18, 1867 to send him a paper for the next general meeting in February. But Stringfellow always proved shy of giving a detailed account of what he was doing.

"I am afraid I could not send you a paper worth reading," he wrote on April 1st. 1868. "I had commenced a paper intending to give you some little of my former experiments but am so bad with rheumatics in my head that I am obliged to give it up . . . . I am getting on very slowly with the model, but I think tolerable satisfactorily and I hope I shall have it finished in time.

"How do you propose to test the light engine? by drawing a weight over a pulley I have one that I made for a larger model very light in proportion to its power. I am afraid I shall not have time to arrange it for testing as I must finish the new model first. One great difficulty I have to contend with is the want of a room sufficiently large to try the model in, as there is a number of little matters that would require to be nicely adjusted before it could possibly be balanced nicely on the wing. I want thoroughly to test the power of the steam engine to carry the model before I brought it up as I have made considerable deviation from my former arrangements."

Stringfellow left no record why he was making the "considerable deviation" from his former model, but the conclusion may be drawn that he was only doing what Cayley and Wenham had suggested, building a triplane, but without fully knowing what the effect would be*.



Stringfellow's Triplane 1868.

He was not very well at this time. He was in his 69th year, *and we find Brearey writing, on May 23rd 1868, to commiserate with him. "I am truly sorry to hear of your continued indisposition. It is depressing to be obliged to contemplate the end of labours which promise so much for the advancement of the science which has at last become acknowledged as such. So far as I am able I am anxious to preserve to posterity the remembrance of the labours and achievements of all those who have given their attention throughout life to the elucidation of the principles of flight. One day a history must be written, and if you possess a photograph of yourself, I should like a copy."*

During the period of the Exhibition three meetings of Members of the Society were held. At the second of these meetings on July 1st, 1868, Stringfellow was present, as also was Wenham, who declared that Stringfellow's triplane was made on a perfectly correct principle.†

*Since this lecture was delivered I have found a report, in the *Kent and Sussex Courier* for September 21, 1877, of a lecture given by Brearey on The Problem of Flight. In the report Brearey is stated to have said, "Mr. Stringellow, some years ago, constructed a frame on which was placed a small steam engine. This contrivance was exhibited at Cremorne, and on one occasion it actually did fly, as far as the space would permit, and its motion was much like that of a pheasant flying. In 1868 the Aeronautical Society held an Exhibition of appliances at the Crystal Palace, and Mr. Stringfellow, acting on a suggestion of Mr. Wenham's, one of the Council of the Society, produced an apparatus in which the wings were placed, one above the other, and this carried a small steam engine and made several trips each day for a fortnight across the central transept of the Crystal Palace."—J.L.P.

†*In an unsigned and undated draft of a letter by Stringfellow, in the possession of the Society, he wrote: "The Model when completed will be about 12 lbs. in weight, water fuel and all and will work about 10 minutes lineal frontage of sustaining planes 21 feet. Superficial area of sustaining planes about 30 feet. Sectional area of the entire machine about 177 inches all angles are reduced as much as possible. Two propellers 21 inches diameter the blades of which regulated to any angle. I shall have no difficulty to work the propllers I should think over 400 revolutions per minute something of course depending on the angle they are set."*

Here Stringfellow made the only reference, in public, to the model of twenty years previously. The actual wording of the *Annual Report* read:

"Mr. Stringfellow; in reply to a question, said the length of his plane is 21 ft. frontage, with 28 ft. of sustaining surface. The plan could be extended to a larger subject with great facility. In making and trying his machines by day he had been so annoyed by followers, that he resolved to make experiments at night. They were favoured by beautiful moonlight, but after being out about ten minutes there was a relaxation in the wings of the machine which he did not understand. He found they were drenched with dew, and nothing could be done. He had tried a great many experiments, and had come to the conclusion that the minimum speed of his little model would be twenty miles an hour.

"Mr. Brearey: It really did fly?

"Mr. Stringfellow: It really did fly in 1847."

The first two sentences giving the span and area of the wings refer to the triplane then being exhibited at the Crystal Palace and the possibility of extending the triplane idea. The rest of the paragraph, down to "and nothing could done" refers to the joint experiments on Bala Down with Henson; and the last sentence "He had tried a great many experiments, etc." refers to the 1848 model.

It was this model about which Brearey had asked, "It really did fly" and to which Stringfellow replied "It really did fly in 1847."

Stringfellow seems to have muddled his date here. Brearey's question was a magnificent opportunity for Stringfellow to say, "It not only flew, but one experiment was so successful at Chard that I was asked to go to London and exhibit at Cremorne where it flew 120 feet."

The chance to stake his claim before all comers had been given him and had not been taken. He made no further comment, either as to where it flew or to the length of any flight, nor did he mention Henson. If ever there was a time to place on record what he and Henson had done together, or what he had done alone, this was the time, especially as Brearey had twice, in letters, asked him to give an account to be included in the Annual Reports.

Wenham, like Chanute, was uncertain about the stability of the triplane, declaring that "he supposed that in rapid rotation there would be some difficulty in keeping a correct angle. It appeared to him that the most efficient form was to have the axis right in front."

By that he meant that the triplane would probably be more stable as a tractor than as a pusher, as Stringfellow had designed it, and that there was a lack of controlling surfaces.

The model was undoubtedly a great attraction and beautifully made. That was Stringfellow's metier. *On September 12 1883, only three months before Stringfellow's death, Brearey wrote to his son,*

"Poor father! so he can do no more! Years ago I was urgently wanting light motive power and would have paid for it but I could not arrange anything satisfactory with your father. I even offered to send down a skilled workman if he would superintend him but he never gave me even a reply. But you and I both know how the 'skilled workman's' tools would have been snatched out of his hands, and how he would have had nothing to do but look on whilst your father worked."

At the following meeting of the Society, on July 3 1868, Stringfellow said he would like to make a few remarks with reference to his own model, the triplane.

"It was not intended for outdoor or rough work. It had sustaining planes, urged forward by propellers at a given angle, at an inclination of about 1 in 60. He had run it along a wire, and after going a little distance had thrown it off. He had driven the model along a room a number of times, and that was how he wished to try this model. It was not constructed to go out, but he was ready to make the attempt. He would throw it off, and if it must fail, it must fail. He disliked exhibitions."

"The Chairman: Do we understand you are prepared to exhibit your model set free in the open air?

"Mr. Stringfellow: I will throw the model off, and if it does not fly it will break its neck. If it gets ahead out of doors, it will fly for some time."

"The Chairman: I am sure all the members of the Society will be very much pleased if you will make the experiment."

Mr. Stringfellow: The model will be ready some time after the next few days."

The Chairman of the meeting, M. le Feuvre, had also been Chairman of the previous meeting and had then commented, "They had the advantage of some description of Mr. Stringfellow's machine, which, in his opinion, was the most practical they had before them yet, so far as the Exhibition was concerned; and he thought if they had only succeeded in bringing that one machine there, they ought to say it had been a great success."*

In face of the Chairman's praise of the triplane and the hope that Stringfellow would demonstrate it, off the wire, one would have at least have expected to have heard that an attempt had been made to do so for the benefit of the members. But no such attempt was publicly made. Following Stringfellow's death in 1883, and not till then, Brearey revealed that the triplane had been tested off the wire.

"In the basement afterwards," (*i.e.* of the Crystal Palace), wrote Brearey, "the author assisted to hold a canvas with which to break the fall of the model when liberated. When freed, it descended an incline with apparent lightness, until it caught in the canvas; but the impression conveyed to us was that had there been sufficient fall, it would have recovered itself."

*James Gillingham, in 1912-13, energetically canvassed for funds to place a memorial bronze wreath and inscription upon the Stringfellow monument in Chard Cemetery. Gillingham did much propaganda work for the fame of Stringfellow, but in his four page leaflet he made a number of misleading statements, of which the following is noted here. "The triplane was entered and flew through the nave. It was awarded the £100 prize, notably for its light engine."

There was no form of control whatever in the triplane, so that its chance of recovery was pretty small.

"It was intended at the last to set the model free in the open country," continued Brearey, "But it was found that the engine, which had done much work, required repairs. Many months afterwards, in the presence of the author, an experiment was tried in a field at Chard, by means of a wire stretched across it. The engine was fed with methylated spirits, and during some portion of its run under the wire the draught occasioned thereby invariably extinguished the flames and so these interesting trials were rendered abortive."

The triplane minus the engine, was bought by Professor Langley for the Smithsonian Institution in Washington. The engine came into the possession of the Society through Mr. Alderson and was placed in the Science Museum on loan from the Society.

Octave Chanute drew attention to the instability of the machine and commented "If the equilibrium be unstable, like that of a bird, it is well enough to have more power than the goose (to which the weight of the triplane had been compared—), but it is much more important to possess its skill."

Brearey, commenting on the triplane in his Memoir of 1883 said "its liberation was not permitted . . . . but it had been observed by several Press Reporters to show a decided tendency to an upward course in its often repeated journeys . . . ."

He hinted that the stability was not too good.

"In the author's experience, however, with every description of models, it is not sufficient to provide suitable surface to weight, even if accompanied with the motive power best calculated to convey it. The balance must be found, and this means *repeated trials* under a condition of freedom of action. A model, especially in the air, is subject to varying conditions, which alter the equilibrium, and the balance can only be secured by intelligent control in the large machine which the model is constructed to represent."

Charles Brooke, a member of the Council of the Society, a Fellow of the Royal Society, author of many papers on experimental and theoretical physics and mathematics, and inventor of a number of self-recording instruments, declared at one of the Exhibition meetings, "I have taken great interest in aerial machines," (He was a President of the Meteorological Society). "I confess I have not seen a machine which would carry out what I believe to be the practical way of flying." Brooke spoke as a member of Council and with considerable authority from a technical point of view. He had seen Stringfellow's triplane.

On July 14 1869, he took the chair at a meeting of the Society when D. S. Brown read a paper on the power required for flight. Brown made no reference to Stringfellow's engine. In a lecture five years later, on May 15 1874, however, Brown referred to the triplane. "He had super-abundance of power, and yet could not release it because he had not overcome this difficulty." (*i.e.* that of stability).

Abel Hureau de Villeneuve, editor of the French monthly paper L'AERONAUTE, *specially came over from France to report the Exhibition. A detailed account of what he wrote was spread over a year and a half's issues. It is one of the longest of the contemporary accounts.*

In the issue of L'AERONAUTE *for May 1870 he wrote, "Mr. Stringfellow's machine, hung from pulleys running on a horizontal iron wire, was drawn forward by the action of its screws. If the planes had lifted at all, the cords which held the machine to the pulleys would have been slackened by the lifting action. But we all saw that these cords remained taut all the time and showed no slackening. Therefore, despite all Mr. Stringfellow's assertions, it is safe to say that a machine like the one exhibited in London is quite incapable of rising."*

At the end of the official report of the Exhibition issued by the Society, there appeared a general note, written in all probability by Wenham, from which the following is quoted:

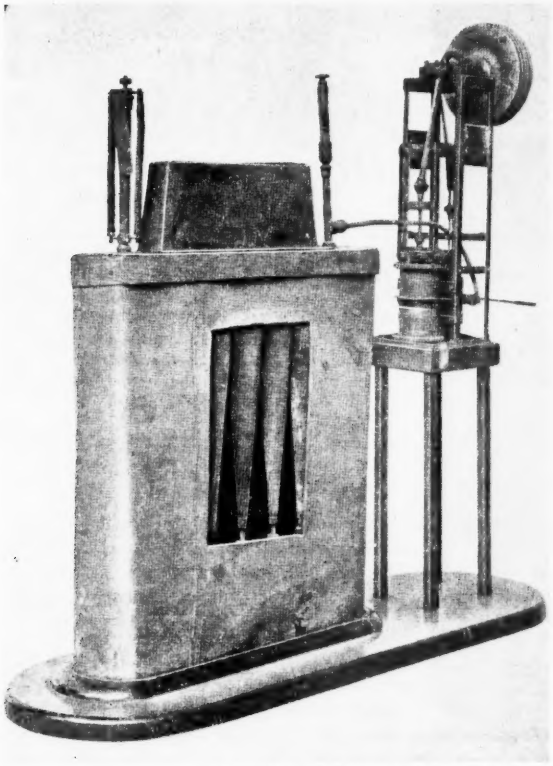
"It remains now to be considered how far the Exhibition has forwarded the science of aeronautics. With respect to the abstruse question of mechanical flight, it may be stated that we are still ignorant of the rudimentary principles which should form the basis and rules for construction. No one has yet ventured to give a correct experimental definition of the primary laws and amount of power consumed in the flight of birds; neither, on the other hand, has any tangible evidence been brought forward to show that mechanical flight is an impossibility for man."

No comment was made about Stringfellow's triplane, but in the Report itself, describing the exhibits, it was said "It was seen by several that after a certain velocity had been attained, the machine left the support of the wire and rose up. On one occasion the wire broke just after the start, but the buoyant power of the planes caused so light a descent that no damage occurred. The model was remarkable for the elegance and neatness of its construction, and was the first experiment adopting the proposed system of superposed aeroplanes to a steam flying machine. Mr. Stringfellow will, no doubt, ascertain the value of these by comparative experiments, with which he is now occupied"*.

One may comment here that nothing further was heard from Stringfellow about the triplane, nor about further experiments. The statement that the machine left the support of the wire and rose up is extremely vague and it need only be added that when it left the wire it went down, and when it was afterwards tried without the wire, it also went down.

The Juror's report gave a long description of Stringfellow's prize-winning engine, beginning with the words "Mr. Stringfellow's boiler and engine, from the

*The *Morning Star* for July 6 1868, recorded, "It was attached by means of a travelling pulley to a horizontal line, which was raised several feet, thus showing the tendency of the machine to rise in the air," and the *Standard* of the same date, "In the course of its flight, the carriage had an evident tendency to rise in the air, as was seen by the fact that the line on which it was suspended, and along which the pulley travelled, was raised several feet."



Courtesy of the Director of the Science Museum

Engine and Boiler of Stringfellow's 1868 Triplane.

cleverness displayed in its construction and design, merits a particular description. The steam engine does not differ from an ordinary one except in the precautions to ensure lightness"†.

†The engine was bought from F. J. Stringfellow by Professor S. P. Langley in 1889 and deposited in the Smithsonian Institution in Washington. The following is the description of the engine as given by the Smithsonian.

"This engine was originally shown at the exhibition of the Aeronautical Society of Great Britain, Crystal Palace, London, in 1868, by John Stringfellow. At that time it was awarded a prize of £100, for being 'the lightest steam engine in proportion to its power.' The prize was augmented by ten £5 contributions from enthusiastic engineers.

"The boiler consists of 28 inverted cones made of very thin sheet copper. It contained 50 ounces of water. The cones are connected at the bottom by pipes and at the top are joined to a cylindrical steam chamber. The fuel used in the long lamp at the bottom was 10 ounces of alcohol. The device on top of the steam chamber at the right is an ingenious combined safety valve and steam gauge.

"The engine is of the simple slide-valve reciprocating type, 2-inch bore and 3-inch stroke. Originally the cylinder was mounted horizontally. The piston rod extended through the piston and cylinder and each end was connected to a cross-head from which a rod and crank drove the propeller; but this gave but one revolution of the propellers to each stroke of the piston, Stringfellow later mounted the cylinder vertically, as shown, to drive a single pulley. From this the smaller propeller pulleys were driven by belts, thus giving a faster rotation.

"Originally the engine was rated 1-1/11 horsepower at a boiler pressure of 100 lbs. and a speed of 300 revolutions per minute. Weight of engine and boiler 13 lbs. The casing at the rear was fitted over the boiler when in use."

There is no suggestion in the Report that there was anything original or novel about the engine. The whole praise was given to its workmanship and the fact it was constructed in the lightest way.

In his letter of May 23rd 1868, already referred to, Brearey replies to a letter of Stringfellow's dated May 21, 1868. Though this letter in its complete form is missing, there are drafts of it in Stringfellow's handwriting in the possession of the Society.

Brearey had written "I don't gather from your letter what is the capacity and capability of the engine and boiler attached to the model you are making, but only of the engine and boiler you have detached from your old model, but which I presume was too weighty for the smaller model . . . . I should decidedly . . . . . exhibit it."

This was the prize winning engine. In the draft of his letter Stringfellow gives details, most of which correspond exactly with the Juror's Report. *In addition he notes "the boiler contains near upon 4 ft. of effective heating surface when charged with 2 quarts of water" . . . Stringfellow gives the weight "of the boiler and fireplace $8\frac{1}{4}$ lb. cylinder with connecting rod etc. $3\frac{3}{4}$ lb. altogether about 12 lb. without supply of water" . . . "Do you think it worth bringing up? Of course I have taken it out of the old model. Should have arranged it in some working frame but shall not have time. I do not know how you purpose judging the capabilities of the light engine."* The editor of *L'Aeronaute*, who, by the way, was specially thanked by the Jury for attending the Exhibition and for the help he had given, in the January 1869 issue of his paper, wrote:

"If the jury had kept strictly to the letter of their programme, they could not have awarded the prize, because the competition was intended for actual engines and all they had to judge were working models. I think they did well not to interpret the rule too narrowly and that they were right to encourage Mr. Stringfellow.

"Quite apart from the merits of his engine, Mr. Stringfellow personally deserved recognition. He had been Henson's partner and Henson was the first man to put a steam engine into a fixed wing aeroplane. Although wrong about the method of using the power of his engine, Henson has earned the gratitude of aeronauts as one of the first inventors of heavier-than-air machines.

Stringfellow's reputation can rest firmly on his work on light steam engines, on his craftsmanship of unusual excellence.*

But only, in a very much lesser degree, despite the time and energy he spent at one stage with Henson and for a brief while after, and the results which were claimed for his work, can he be said to have deserved the aeronautical reputation given to him by historians.

*Brearey, in his Memoir of 1883, wrote: "The best of Mr. Stringfellow's Exhibits at The Aeronautical Exhibition . . . was his light steam engine for aerial purposes."

The first Aeronautical Exhibition, Crystal Palace 1868, showing the Stringfellow Triplane Model and other exhibits. There were altogether seventy-seven exhibits, including engines, lighter- and heavier-than-air models, kites and plans of projected machines. The X at the bottom of the print by the foot of the figure on the left indicates Stringfellow.

" As the figure of Henson emerges from its shadowy background," said Paul Johnston, " it is becoming more and more apparent that he should be given equal credit with his collaborator for the first step in the final development of heavier than air flight, even though he was not present to witness the final triumph."

9. The Final Years

The Aeronautical Exhibition at the Crystal Palace in July 1868 saw the high lights of Stringfellow's experiments.

With the prize money for his engine (paid in instalments, by the way, for the Society was very hard up and had to call upon the guarantors) Stringfellow built a room in Chard about 70 feet in length, with the intention of carrying out further experiments. Brearey kept in touch with him until within a few months of his death, and many letters of Brearey's to him indicate they were on terms of friendship. *In July 1869 Stringfellow suggested to Brearey that he (Brearey) should read a paper on flying and Brearey agreed provided Stringfellow gave to him all the necessary help he would require.* This lecture started Brearey on a series of lectures throughout the country, in which he not only kept the name of the Aeronautical Society familiar to an ever widening circle of people, but learnt to make flying models himself which he demonstrated at most of his lectures with considerable success.

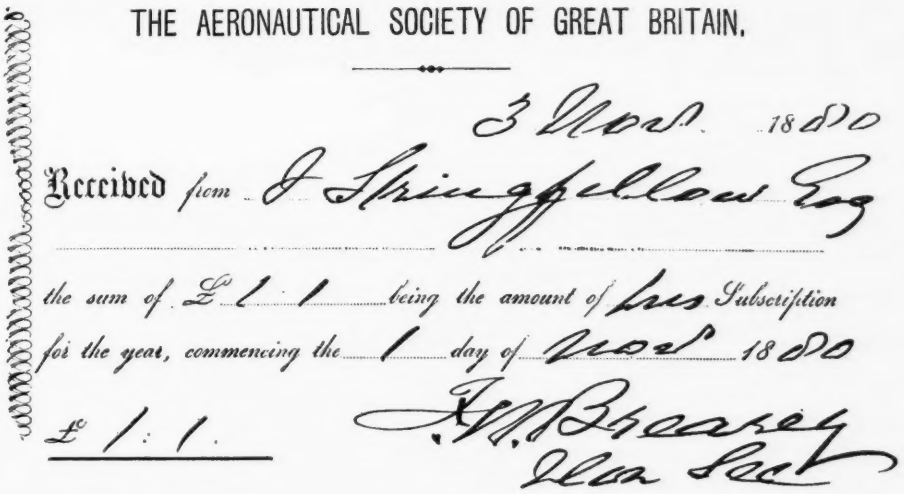
Well over a score of letters from Brearey from 1869 to 1881 have been preserved and not only reveal some of Stringfellow's character, but the fact that he was not well-to-do and often unable to respond to the demands made to him to make an engine specially for an aeronautical experiment. He was certainly not rich enough to be able to afford to neglect the business for which he was trained, lace-making machinery. Often Brearey offered to forego his annual guinea subscription. His faculties steadily failed, though he hankered from time to time to continue his experiments.

From the time of the close of the Exhibition until his death some fifteen years later, there is nothing on record to indicate any further achievement or advance, in his ideas. In fact in the last recorded letter of Brearey to him, dated December 7 1881, Brearey wrote *" I am very glad to find that you are still hankering after realising the old dream—but I don't agree with you as to gas."*

Brearey was, perhaps, the one person in the best position to judge Stringfellow's capabilities and experimental outlook. His letter to his son, of September 12, 1883, indicates that Stringfellow was not only a first-class craftsman, but one who believed he was better than most—which he probably was.

Brearey had no doubt that Stringfellow's real strength lay in his ability to construct light steam engines. *" My dear old friend," he wrote on April 26, 1880, " All my investigations into the subject of light boilers have resulted in confirming my original opinion* VIZ *' There is nothing to equal yours.' "*

Even in Stringfellow's 81st year Brearey was hopefully trying what he had failed to succeed in doing


THE AERONAUTICAL SOCIETY OF GREAT BRITAIN.

3 Nov. 1880

Received from J. Stringfellow Esq

the sum of £1 1 being the amount of his Subscription for the year, commencing the 1 day of Nov 1880

£1 : 1.

F. W. Brearey Hon Sec

Receipt for Stringfellow's annual subscription.

over the years the two had known each other, to get him to build a light engine to order. In the second half of this letter Brearey asked for an engine of 5/6 h.p. weighing less than 40 lb.

Yet in the Memoir of his old friend, Brearey made no comment of his own on the experiments at Chard or Cremorne, as to their value or otherwise. He merely repeats, word for word, the account he published in 1869. Of the 1868 triplane model he quotes what the press saw of its flights along the wire in the Crystal Palace, but does not say whether he agrees or not with their statements. His own report is that he saw it tried off the wire in the basement of the Palace and in a field at Chard, with unsuccessful results. He also, as Chanute had done, questioned its stability.

Relating what happened after the Exhibition Brearey noted that failing eyesight prevented Stringfellow from doing any fine work.

"Three months before his death he felt that the work he was executing for its improvement was a mistake, and to his son he said 'I've hung it up, Fred. I shall touch it no more. I hope I have not spoiled it for you.'

"Had his cunning not departed from him, many a light engine would have been turned out in satisfaction of the enquiries and demands of aeronautical inventors."

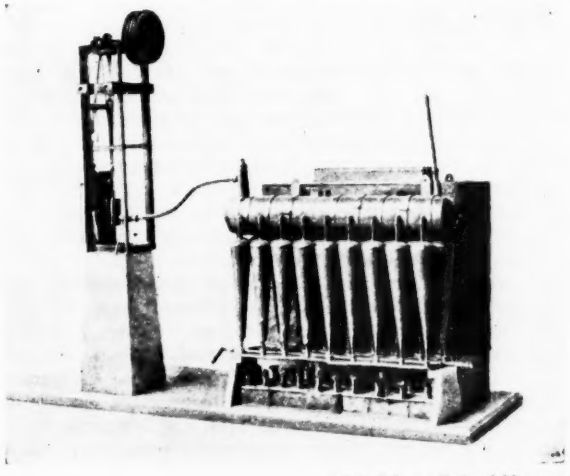
Of his aeronautical endeavours as such, patient, arduous, and meticulous as they were in many ways, all that Brearey could say was:

"All we are justified in concluding is that John Stringfellow considered that aerial navigation was capable of accomplishment and that he gave much time and means to its elucidation."

Not a single word of praise, nor even a suggestion in that conclusion, of any successful flying model experiments, from the one man who was in the position to give that praise.

This assessment does not deny an important place in the history of aviation to John Stringfellow, but it does attempt to show that William Samuel Henson holds a place at least as important, and to add that if John Stringfellow had not met and worked with Henson, his name would not be known in aeronautical history.

The work of Henson and Stringfellow cannot be separated, any more than that of Orville and Wilbur Wright.


(United States National Museum)

The prize-winning engine and boiler of 1868 as subsequently altered by Stringfellow.

"We who survive to pass judgment upon the results of a man's life, should be very careful how to exercise that judgment. It is much too solemn a retrospect for the toleration of a flippant analysis. All we are justified in concluding is that John Stringfellow considered that aerial navigation was capable of accomplishment and that he gave much of his time and means to its elucidation. In the future years, when this end is accomplished—as it surely will—his name will be included in the roll of fame."—F. W. BREAREY.

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Special Note.—Over forty autographed letters from F. W. Brearey, John Stringfellow and F. J. Stringfellow have been studied and many quoted in this paper for the first time. The unknown letters consulted number 35, and there are many others not relevant to this particular paper, in the possession of the Society covering aspects and personalities of the early history of the Society.

APPENDIX I

HENSON'S SPECIFICATION, 1842

A

A.D. 1842 . . . . No. 9478

Locomotive Apparatus for the Air, Land, and Water

HENSON'S SPECIFICATION

TO ALL TO WHOM THESE PRESENTS SHALL COME, I, William Samuel Henson, of No. 26, New City Chambers, Bishopsgate Street, in the City of London, Engineer, send greeting.

WHEREAS Her present most Excellent Majesty Queen Victoria, by Her Letters Patent under the Great Seal of Great Britain, bearing date at Westminster, the Twenty-ninth day of September, in the sixth year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said William Samuel Henson, Her especial licence, full power, sole privilege, and authority, that I, the said William Samuel Henson, my exors, admors, and assigns, or such others as I, the said William Samuel Henson, my exors, admors, or assigns, should at any time agree with, and no others, from time to time and at all times during the term of years therein expressed, should and lawfully might make, use, exercise, and vend, within England, Wales, and the Town of Berwick-upon-Tweed, and also in all Her said Majesty's Colonies and Plantations abroad, my Invention of "Certain Improvements in Locomotive Apparatus and Machinery for conveying Letters, Goods, and Passengers from Place to Place through the Air, part of which Improvements are applicable to Locomotive and other Machinery to be used on Water or on Land;" in which said Letters Patent is contained a proviso that I, the said William Samuel Henson, shall cause a particular description of the nature of my said Invention, and in what manner the same is to be performed, to be inrolled in Her said Majesty's High Court of Chancery within six calendar months next and immediately after the date of the said in part recited Letters Patent, as in and by the same, reference being thereunto had, will more fully and at large appear.

NOW KNOW YE, that in compliance with the said proviso, I, the said William Samuel Henson, do hereby declare that the nature of my said Invention, and the manner in which the same is to be performed, are fully described and ascertained in and by the following statement thereof, reference being had to the Drawings hereunto annexed, and to the figures and letters marked thereon (that is to say):—

The Invention relates, first, to the constructing of locomotive machinery and apparatus for conveying letters, goods, and passengers from place to place through the air; and, secondly, to improvements in constructing steam boilers for the generating of steam to give motion to locomotive machinery in the air, and also locomotive and other machinery used on water or on land; and in order that my Invention may be fully understood and readily carried into effect, I will proceed to describe the means pursued by me; and in order that the description hereafter given may be rendered clear, I will first shortly explain the principle on which the machine is constructed. If any light and flat at or nearly flat article be projected or thrown edgewise in a slightly inclined position, the same will rise on the air till the force exerted is expended, when the article so thrown or projected will descend; and it will readily be conceived, that if the article so projected or thrown possessed in itself a continuous power or force equal to that used in throwing or projecting it, the article would continue to ascend so long as the forward part of the surface was upwards in respect to the hinder part, and that such article, when the power was stopped, or when the inclination was reversed, would descend by gravity only if the power was stopped, or by gravity aided by the force of the power contained in the article, if the power be continued, thus imitating the flight of a bird.

Now, the first part of any Invention consists of an apparatus so constructed as to offer a very extended surface or plane of a light yet strong construction, which will have the same relation to the general machine which the extended wings of a bird have to the body when a bird is skimming in the air; but in place of the movement or power for onward progress being obtained by movement of the extended surface or plane, as is the case with the wings of birds, I apply suitable paddle wheels or other proper mechanical propellers worked by a steam or other sufficiently light engine, and thus obtain the requisite power for onward movement to the plane or extended surface; and in order to give control as to the upward and downward direction of such a machine, I apply a tail to the extended surface, which is capable of being inclined or raised, so that when the power is acting to propel the machine, by inclining the tail upwards, the resistance offered by the air will cause the machine to rise on the air; and, on the contrary, when the inclination of the tail is reversed, the machine will immediately be propelled downwards, and pass through a plane more or less inclined to the horizon as the inclination of the tail is greater or less; and in order to guide the machine as to the lateral direction which it shall take, I apply a vertical rudder or second tail, and according as the same is inclined in one direction or the other, so will be the direction of the machine.

Having thus given the general principles on which the machinery and apparatus, according to the first part of my Invention, are constructed, I may remark, that it will be evident that the principal objects to be considered in the construction of such a locomotive machine are lightness with strength in respect to the machine itself, and lightness with respect to quantity of power offered by the engine employed; and I would here state, that although I shall hereafter describe a particular construction of machine and engine to be used in propelling the same, yet I do not confine myself to the details thereof, as variations may be made, so long as the general principle of construction be retained.

Description of the Drawings A.

Figure 1 represents a machine and apparatus constructed according to the first part of my Invention, the covering fabric being removed, in order that the manner of framing the parts together may be more readily traced. Figure 2 shows the same view of the machine, with the covering applied. Figure 3 shows an under side view of the machine with the covering fabric in its place; the view shown by this Figure being one offered to the viewer when standing below the machine, and looking upwards; the other Figures of these Drawings showing separate parts, in order that the details of construction may be more fully understood than could be the case by simply examining the perspective Drawings of the machine shown at Figures 1, 2 and 3; and some of these details are shown on a larger scale than the same parts in the other Figures. Figure 4 is a side view of the main frame or extended surface, of which the machine is principally constructed. Figure 5 shows a plan of the tail for controlling the direction of the machine in its upward and downward direction. Figure 6 shows a side view of the same tail. Figure 7 shows one of the framed bars which run from front to back of the machine, which I prefer to be of wood or bamboo, in order that I may obtain lightness with sufficient strength. Figure 8 shows two sections of the hollow bars of wood, or other suitable material or materials for the bars, of which the main frame is composed. Figure 9 shows a plan and side view of the mode by which I fix and tighten the suspending wires and wire braces or rigging of the machine.

On an examination of the Drawings it will be seen that the machine consists of an extended surface or plane extending on either side of a car or vessel, in which the engine, fuel, passengers, goods, and letters are carried, the nature of which vessel or car is more clearly shown in the plan and side section, Figures 10 and 11, which are on an enlarged scale when compared with the other Figures of these Drawings, such car or vessel being framed together with a view to strength and lightness; and the outline shows the position of a steam-boiler and engines for giving motion to the propelling machinery hereafter explained, such engine and boiler being fixed rather forward in the car or vessel, because from experiment I have found it desirable that the weight carried by such a description of locomotive machine should be forward; and it will be seen that the car or vessel has three wheels, in order that when the car comes to the earth it may run freely without injury, and owing to the great control which the tails offer in governing such a machine in descending, the car may be caused to come to the earth in so flat an incline that in taking the earth very little, if any, shock will be perceived by the passengers. In the car two masts are fixed, which rise above the upper part of the car, as is shown, and from the upper parts of these masts the two surfaces or planes on either side of the car are suspended, and the framing of those surfaces or planes are braced to the lower ends of such masts; thus, in fact, making the whole machine as one trussed beam of very light construction, yet offering the requisite stiffness for its purpose. I have not thought

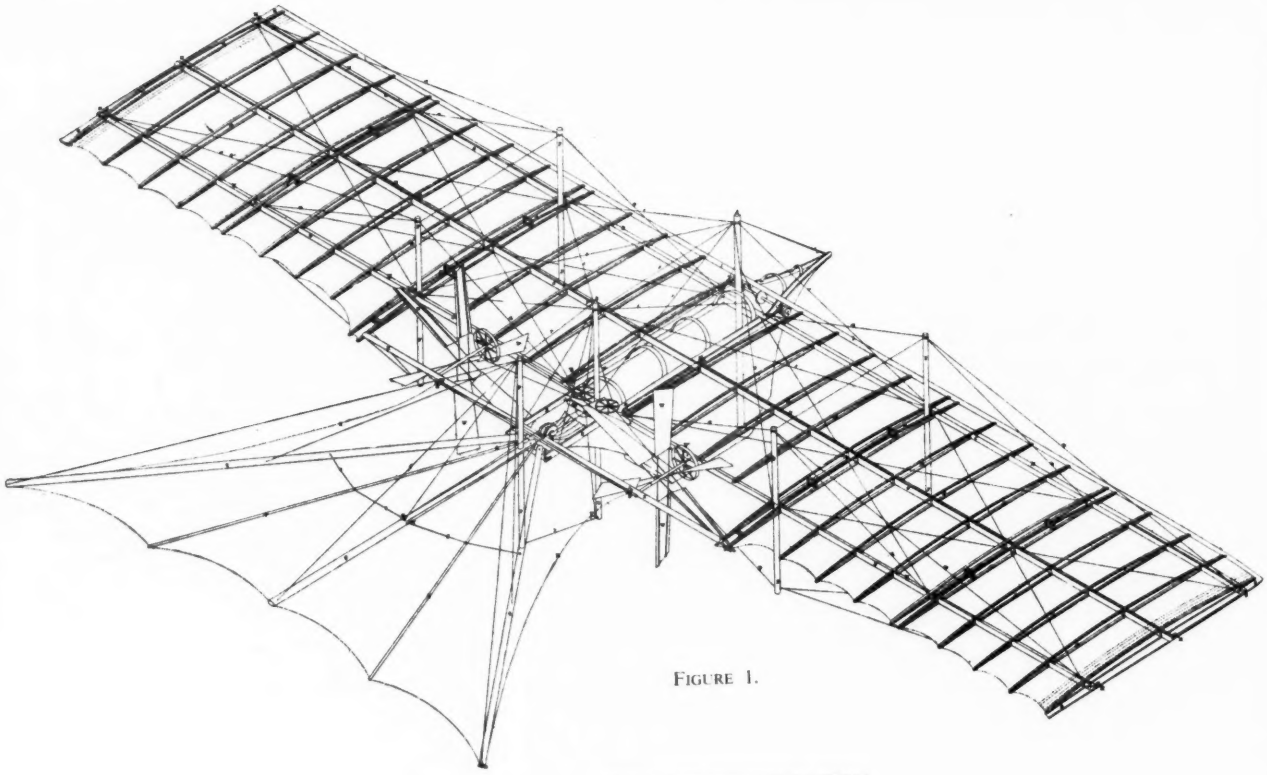


FIGURE 1.

HENSON'S SPECIFICATION

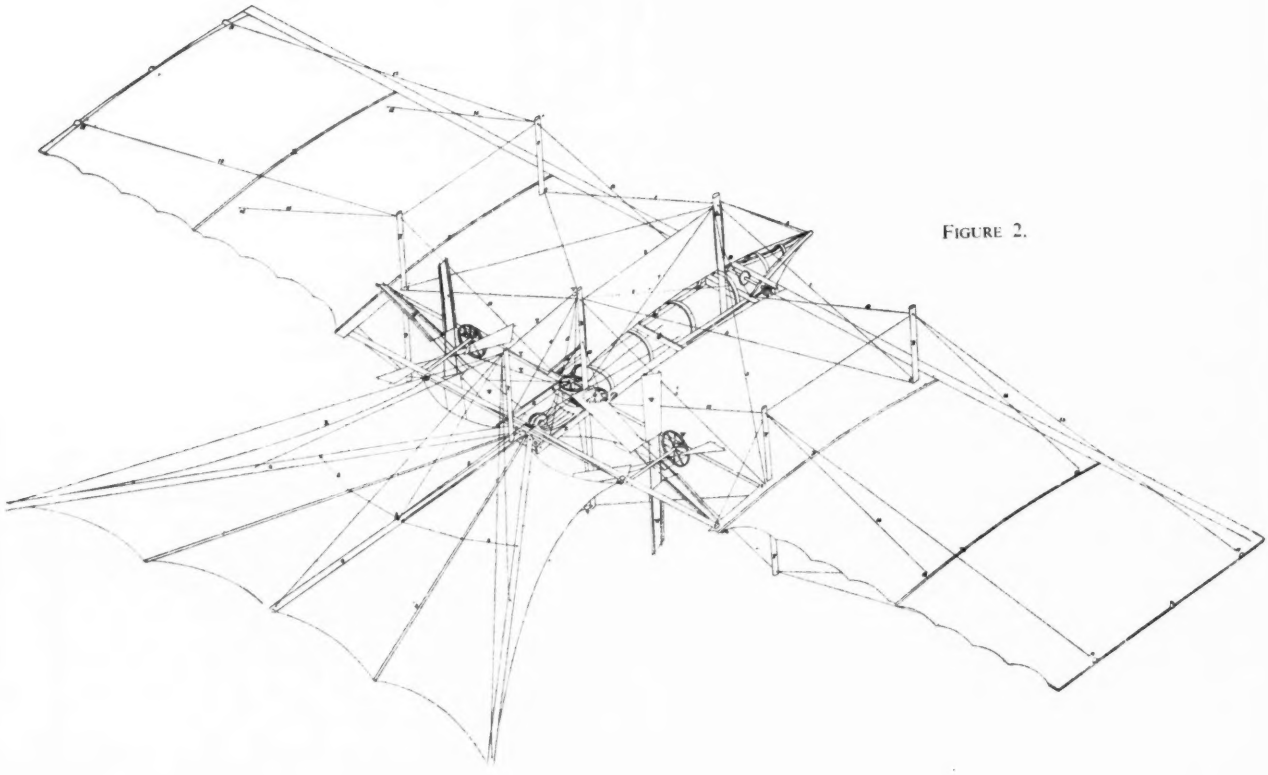
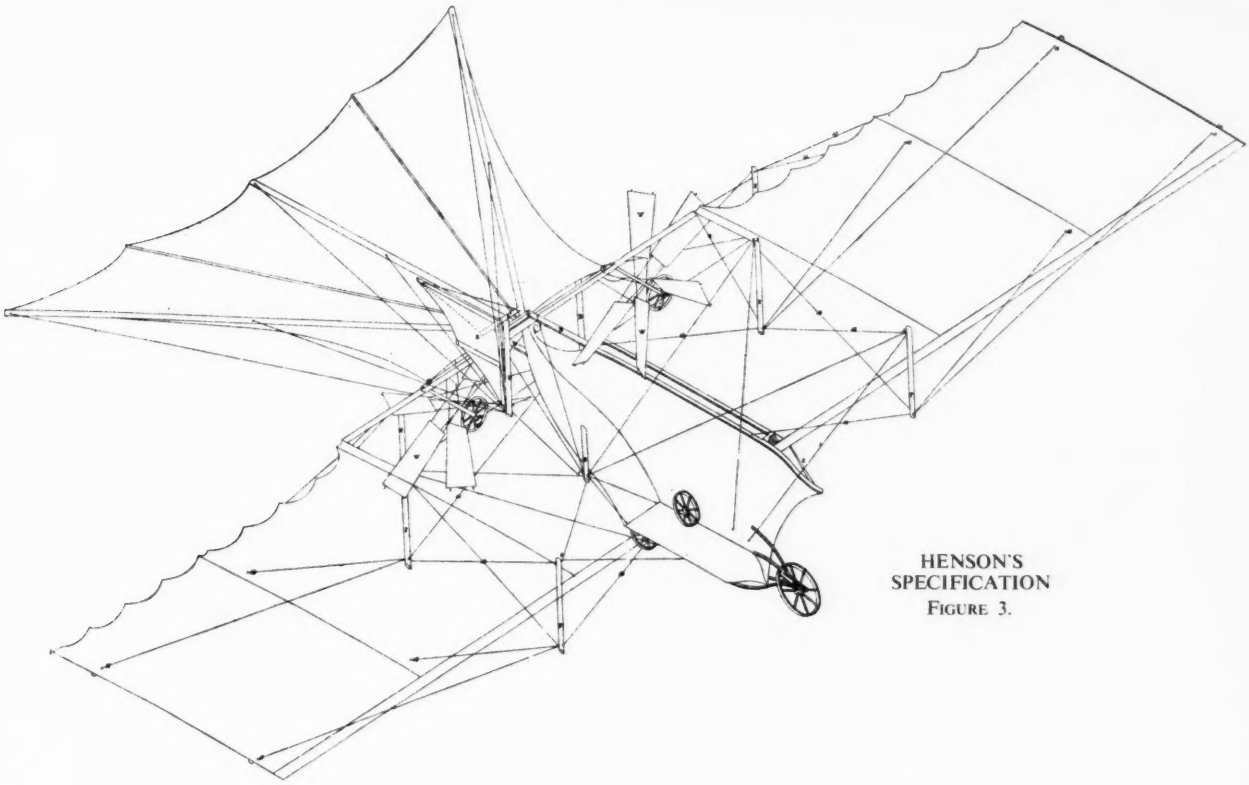


FIGURE 2.



HENSON'S SPECIFICATION
FIGURE 3.

it necessary to show the interior arrangement of the car, as the same will readily be fitted up according as it is more intended for passengers or for goods, or otherwise. The suspending of the framing is by numerous wires, which I prefer to be of an oval section, so as to offer as little resistance as possible in passing through the air, such wires proceeding in various directions, as is shown in the Drawings. A is the foremast and B the hindmast; from the upper parts of these masts descend suspending wires (1), (1), to the points (2), (2), of the lateral main bars C, D, on either side of the car, thus suspending those main bars C, D, from the masts; and there are other suspending wires (3), (3), which, proceeding from the upper parts of the mast, cross each other, and are made fast at the same points (2), (2), of the main bars, C, D; and there are corresponding bracing wires proceeding from the lower ends of the masts to the same points (2), (2), of the main bars, as is shown; and there are also suspending wires (4), (4), descending from the mast B, and affixed to the hinder projecting frame E, E, which carries the tail of the machine. (5), (5), are suspending wires from the upper part of the foremast A to the front part of the car, (7) is a suspending wire affixed at the upper part of the foremast; it is made fast to the hinder framing of the car. (8) is a similar suspending wire made fast to the upper part of the hindmast B, and also to the fore part of the car; and there is a wire brace (9) affixed to the upper part of each mast, and between the two masts above the car is stretched a sail, shown in Figure 2, which facilitates the lateral steering of the machine. (10), (10), are suspending wires from the masts to the sides of the car, and (11), (11), are braces to correspond with the suspending wires (10). At the points (2), (2), of the main bars C, D, on either side of the car, are uprights F, F, affixed to the main bars, C, D. Ascending above and descending below those bars, and from the upper ends of these uprights, proceed suspending wires (12), (12), to the main bars, C, D, near the sides of the car; and there are corresponding wire braces (13), (13), from the lower ends of the uprights to the main bars near the car, as is shown. From the upper and lower ends of the uprights also proceed other suspending bracing wires (14), (15), which are respectively made fast at the points (16), (17), of the main bars C, D; and there corresponding brace wires proceeding from the points (16), (17), to the lower ends of the uprights F, as are shown in the Drawings; and it will be seen that the two uprights F, on either side of the car, are braced together by diagonal brace wires (18), (18); the object of all which suspending and brace wires is to obtain great stiffness and strength with lightness of structure. G is the central main bar, and it will be seen that the main bars, C, D, G, are fixed together by means of the end pieces H, H; and it will be understood that the main bars, C, D, are made hollow in order to obtain lightness and stiffness, and the main bar G is shown to be a plate of wood on edge. In the front of the projecting planes, on either side of the car, there is fixed the front bar I; and it will be seen that the bars C, D, G, and I, are combined into one framing with the car by means of the framed beams or bars H, J, K, and the whole of the under and upper surfaces of the projecting planes are to be covered with a strong close fabric. I prefer strong oiled silk for this purpose; and such coverings are affixed to light frames similar to the framed beams J, K, at the points (19), (19), which are capable of sliding to and fro on the main bars C, D, and G, the parts of the covering fabrics being fixed

FIGURE 4.

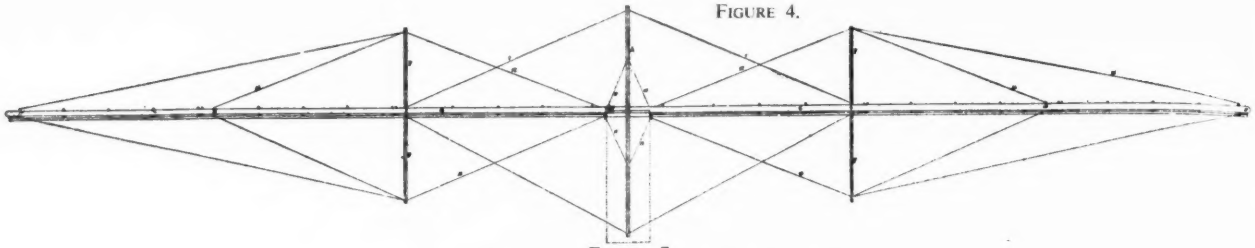


FIGURE 7.

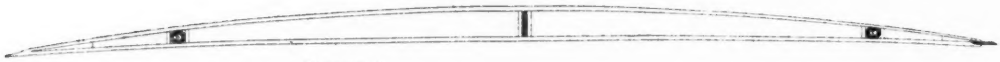


FIGURE 6.

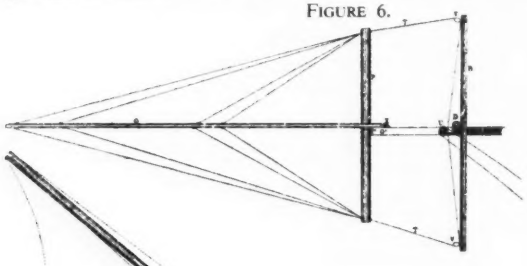
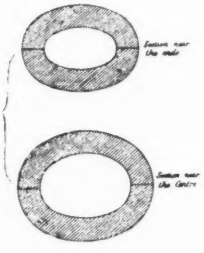


FIGURE 8.



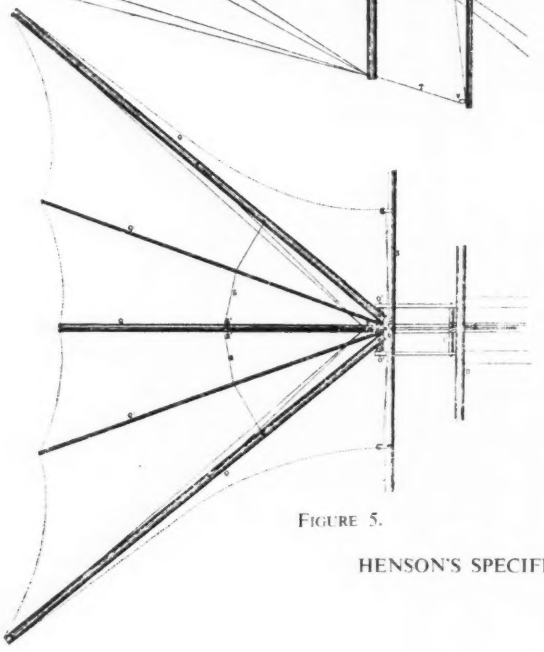


FIGURE 5.

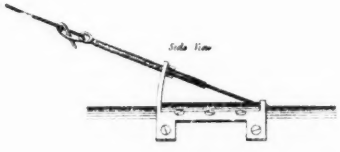
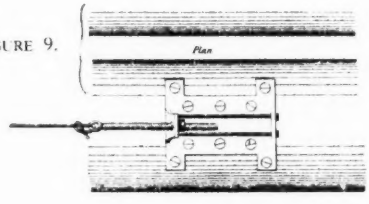


FIGURE 9.



HENSON'S SPECIFICATION

to the main framing at the beams H, J, K. Thus the portion of the covering from the outer end of either side plane can be slided from the beam or bar K to the outer, and the next portion of the covering can be slided back from the beam or framed bar J to the framed bar K, and the next part of the covering can be slided back to the framed bar or beam J; and this is accomplished by means of cords N from the windlass L, in the fore part of the car, which cords pass over the pulley M, M, the cords being suitably connected with the sliding frames to which the covering fabrics are affixed, the object being that the coverings may be drawn up when the machine is not in use. The tail which governs the machine in its upward and downward movements is affixed to the axis O, the ends of which move in bearings at O^1, and the tail is suspended from the upright P, which is also affixed to the axis O; this tail consisting of three bars Q, Q, Q, and the smaller bars Q^1, which are all affixed to the axis O, which bars are covered with a suitable fabric, and I prefer strong oiled silk for such purpose. These bars are capable of being separated or opened out by means of the cords R, R, passing partly round pulley R^1 to the car, where they are made fast; and the bars Q are capable of being drawn together by the cords S, S, which pass partly round pulleys S^1, and thence go to the car, where they are made fast. The requisite up-and-down motion is communicated to this tail by means of the cord T, which is made fast at either end of the upright P. It then passes partly around the pulleys V at the upper and lower ends of the hindmast B; the cord then takes several turns around the windlass or barrel U, which is worked by any convenient means, which I have not thought it necessary to show, as the same will readily be applied by a mechanic; and according as the windlass or barrel U is turned in one direction or the other, so will be the inclination of the tail, and such inclination will be more or less upwards

HENSON'S SPECIFICATION

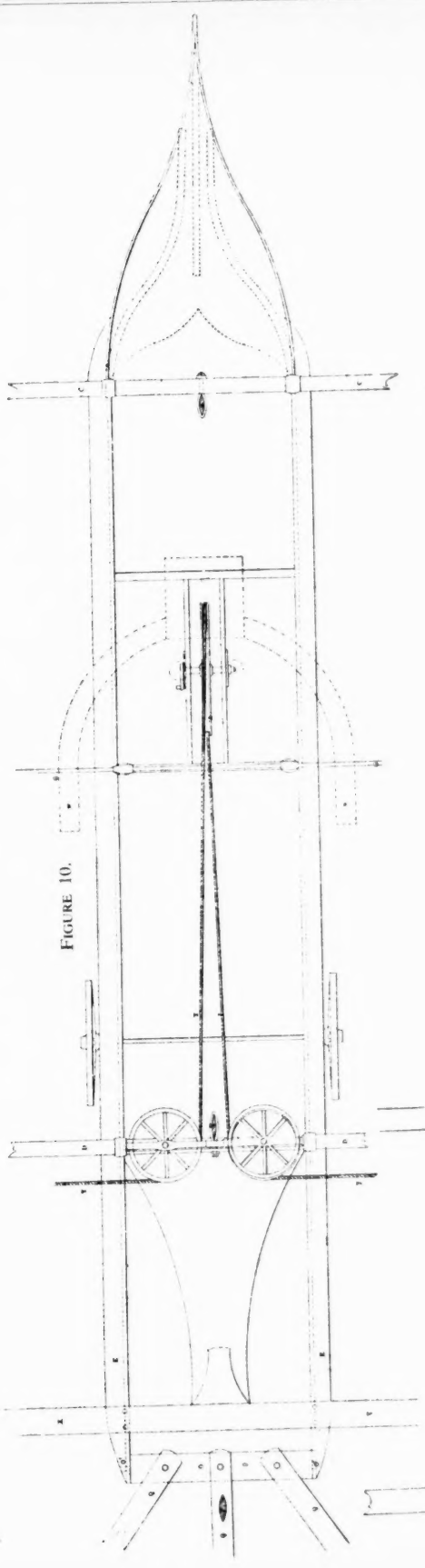


FIGURE 10.

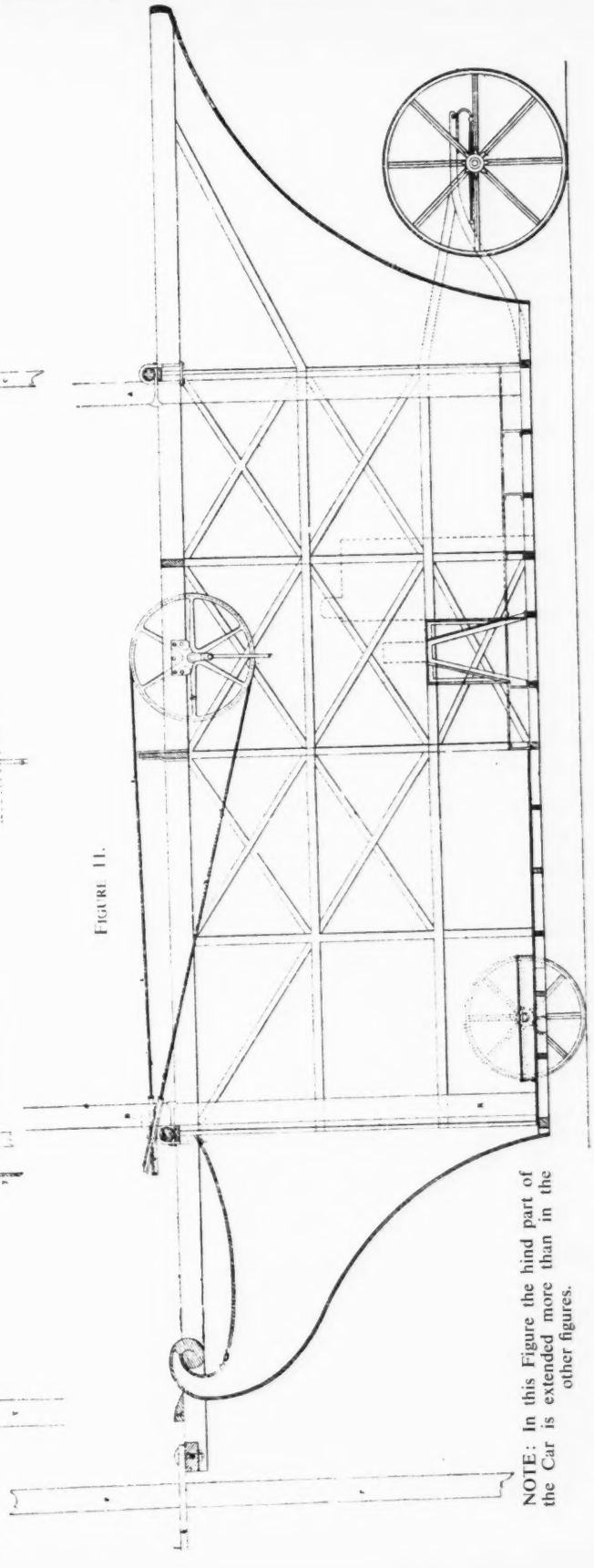


FIGURE 11.

NOTE: In this Figure the hind part of the Car is extended more than in the other figures.

or downwards, according to the directions desired to be obtained to the machine. I have not thought it necessary to enter into every detail of the means of framing and connecting the parts together, as these parts of the construction will readily be performed by proper workmen, taking care that all parts are well and strongly joined. I would here observe, that a machine constructed as I have above described may have propellers of various constructions applied thereto, but I believe paddle wheels with oblique paddles will be most suitable for the purpose. I will therefore now describe the application of such paddle wheels, and the best means I am acquainted with for giving motion thereto. W, W, are two paddle wheels, their shafts or axes turning in bearings carried by the main bar D and the bar X, as is shown; the paddles of these paddle wheels being set at about an angle of 45°, to their respective axes of motion, and to the axes of these wheels are affixed the pulleys W^1, which receive the endless band or cord Y, which receive its motion from the steam or other proper engine carried by the car; and although I do not confine myself to the use of any particular construction of engine for such purpose, I will hereafter explain the best construction of steam-engine I am acquainted with for the purpose of giving motion to suitable propellers for a locomotive engine constructed according to the first part of my Invention. Z is the lateral steering tail or rudder, which consists of a triangular frame covered with fabric, as before explained in respect to the other parts; this rudder is hung on the upright P, and is caused to move in either direction by means of cords passing into the car, such cords being affixed to the ends of the bar Z^1. In starting the machine, I prefer to do so from an inclined plane or the side of a hill, and I allow the machine to run forward down the incline, the propellers being first set in motion, when it will be found that in a short time they will act sufficiently upon the air to cause the machine to leave the incline and proceed in any desired direction. In constructing the machine above described the following are the best proportions which I am enabled to lay down from the various experiments which I have been enabled to make; at the same time, I do not confine myself thereto:—There should be about one square foot for each half pound weight of the machine, including machinery, fuel, and load; and the following are the dimensions of the machine I am making, and which will weigh about three thousand pounds. The surface of the planes on either side of the car will measure four thousand five hundred square feet, and the tail one thousand five hundred more, with a steam engine (high pressure) of twenty-five to thirty horse power.

Having thus described the nature of a locomotive machine constructed according to the first part of my Invention, I will proceed to explain a steam-engine shown in Drawing B, which I have arranged for giving motion to suitable propellers, and I will also describe my improved construction of steam boiler for supplying such or other construction of steam-engine with steam, which improved construction of steam boiler constitutes the second part of my Invention. Figure 12 represents a front view of a steam-engine constructed suitably for giving motion to the propellers of a locomotive machine such as is above described. Figure 13 shows a side view thereof, and the Drawing also shows the steam-engine in connexion with a steam boiler, the peculiar construction of which constitutes the second part of my Invention, Figure 13 showing a side section of such boiler. Figure 14 shows a front section thereof. Figure 15 shows a plan of the boiler in section, taken just above the fire bars; and Figure 16 shows a plan in section, taken at the upper part just above the series of conical vessels of which the boiler is composed. The other separate views show the description of steam cocks used for admitting the steam to flow from the boiler into the steam cylinders, and from the steam cylinders into the atmosphere *a*, *a*, are the steam cylinders, each cylinder having four steam cocks *b*, *b*, and two *c*, *c*, two (*b*, *b*), for admitting steam into the steam cylinders, and two (*c*, *c*), for permitting the steam to escape into the atmosphere. *d*, *d*, are the steam pipes from the boiler to the steam cylinders; and *e*, *e*, are the eduction steam pipes from the steam cylinders; *f*, *f*, are the piston rods, the cross heads of which are guided by the rods *g*, *g;* to the cross heads are attached the connecting rods *h*, *h*, which give motion to the cranks *i*, *i*, affixed on the main or driving shaft *j*, on which there is a suitable drum or pulley *k*, for giving motion to a suitable band or cord for driving the propellers, as shown in the Drawings. *l*, *l*, *m*, are rods worked by eccentrics for giving motion to the plugs of the steam cocks for admitting the steam into and from the steam cylinders; and *n*, *n*, are pump rods for pumping water into the boiler. *o*, *o*, are two uprights or pillars between the engines and the bearings of the main shaft. The boiler consists of a peculiar arrangement of a series of conical vessels, *p*, *p*, *p*, and *q*, *q*, *q*. The conical vessels *p*, *p*, *p*, are affixed at the lower ends into water pipes *r*, *r*, *r*, thus dividing the boiler into two compartments, each of which has its grate of fire bars, as is shown, and the vessels *p*, *p*, are connected to the vessel *q*, *q*, by means of short pipes p^1. The upper ends of the conical vessels *p*, *p*, enter into and are affixed to the cylindrical vessels *s*, *s*, and *t*, the three vessels *s*, *s*, and t, being connected together, as is shown. The conical vessels *q*, *q*, are short vessels which are affixed to and enter into the vessels *s*, *s*, and *t*, as is shown. The steam passes off at the valve *v* to the steam pipe, and the quantity passing away from the boiler may be regulated at pleasure by the valve. The boiler is enclosed in the case *u*, *u*, as is shown, in which are found openings for the fire doors and ash-pit doors, *w*, *w*, being the flues which convey off the products of combustion to the chimney. The object of this arrangement of boiler is to obtain great strength with lightness, at the same time extensive heating surfaces, in order to obtain the greatest power in the least space. I prefer to construct such steam boiler of copper, the screw joints being of brass, but I do not confine myself thereto. It will be evident that by thus combining a series of conical vessels *p*, *p*, *p*, and *q*, *q*, *q*, with the pipes *r* and the vessels *s*, *s*, and *t*, a very simple construction of boiler will be obtained, and owing to the larger parts of the conical vessels being upwards, the heat of the furnace will be most advantageously applied. I would remark, in respect to this part of my Invention, that I do not confine myself to the precise details shown, provided the peculiar combination of conical vessels with the other parts as above described be retained.

Having thus described the nature of my Invention, and the best means I am acquainted with for performing the same, I would have it understood that what I claim is,—

First, the mode of constructing locomotive apparatus and machinery for conveying passengers, goods, and letters through the air as above described.

And, secondly, I claim the mode herein explained of constructing steam boilers applicable to locomotive machinery, such as above described, and also engines used on land or water.

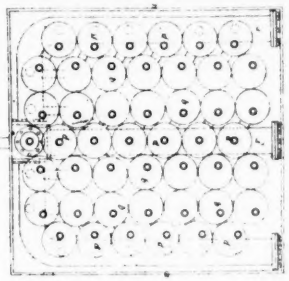


FIGURE 16.

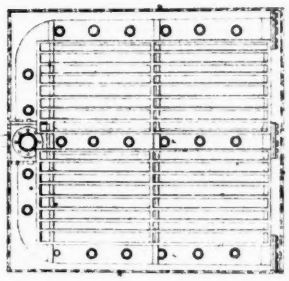


FIGURE 15.

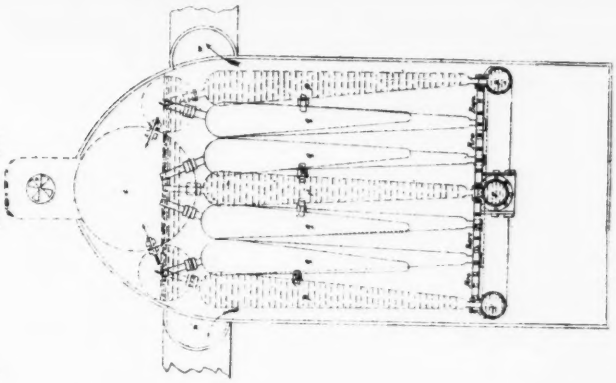
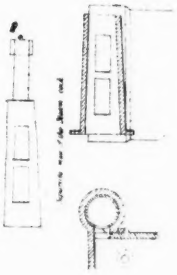


FIGURE 14.

HENSON'S SPECIFICATION



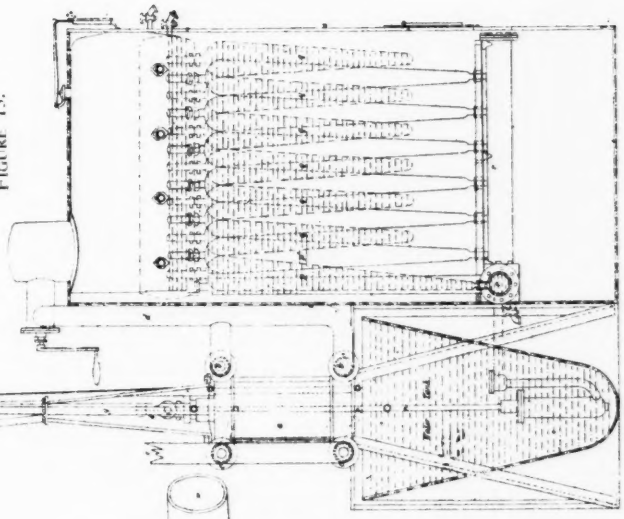


FIGURE 13.

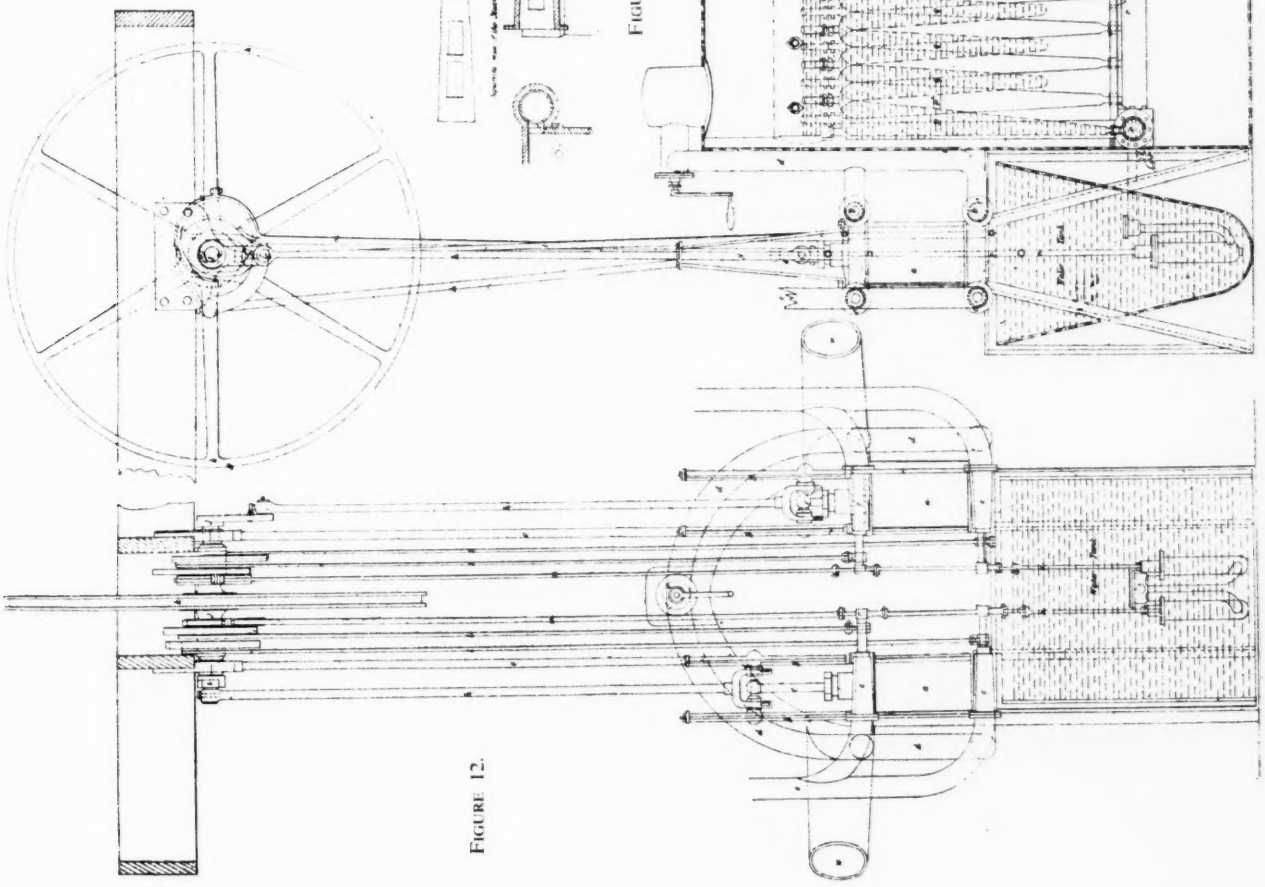


FIGURE 12.

In witness whereof, I, the said William Samuel Henson, have hereunto set my hand and seal, this Twenty-eighth day of March, in the year of our Lord One thousand eight hundred and forty-three.

WILLIAM SAMUEL (L.S.) HENSON.

AND BE IT REMEMBERED, that on the Twenty-eighth day of March, in the year of our Lord 1843, the aforesaid William Samuel Henson came before our said Lady the Queen in Her Chancery, and acknowledged the Specification aforesaid, and all and everything therein contained and specified, in form above written. And also the Specification aforesaid was stamped according to the tenor of the Statute made for that purpose.

Enrolled the Twenty-ninth day of March, in the year of our Lord One thousand eight hundred and forty-three.

APPENDIX II

THE AGREEMENT BETWEEN HENSON AND STRINGFELLOW, 1843

Memorandum of an agreement entered into by Mr. John Stringfellow, of Chard, in the County of Somerset, of one part, and Mr. Wm. Saml. Henson, of No. 7, Ralph Place, near Trinity Square, of the Borough of Southwark, of the other part.

Whereas it is intended to construct a model of an Aerial Machine to be employed in such a manner as the parties above named shall consider best and most profitable.

1st. It is agreed, if considered necessary, to take out patents for the same jointly, but be it understood that this agreement does not extend to England except for such parts as are improvements upon patent already taken out in England.

2nd. That all moneys advanced to be considered as lent and to be deducted from the profits that may arise hereafter.

3rd. That all profits after deducting expenses be equally divided.

4th. That it is the intention of this agreement that the parties above named shall be on perfect equality as regards carrying out and working the same.

5th. It is intended at a future time, if considered necessary and desirable, to enter into an agreement more definite and explicit, according as circumstances may arise to require it.

6th. That the parties hereby pledge themselves in honour to each other to do all that lies in their power towards carrying out the objects of this agreement.

7th. That nothing herein mentioned shall be construed into a partnership beyond carrying out jointly the objects of this agreement.

(Signed) W. S. HENSON.

(Signed) J. STRINGFELLOW.

December 29th, 1843.

VOTE OF THANKS FOLLOWING THE LECTURE

MR. HOLLIS WILLIAMS (*Fellow*): The researches that had been carried out had certainly given quite a new aspect to this matter. It still showed that these two pioneers did valuable work but not quite as had previously been thought. He would ask Dr. Still, alternate Chairman of the Yeovil Branch and Technical Director of Normalair, to propose the vote of thanks.

DR. E. W. STILL (*Fellow*): They were greatly honoured at having been given the lecture at Yeovil and he was very pleased to be asked to pay tribute to these two gentlemen for coming down and giving the lecture. It gave him great pleasure to propose the vote of thanks on behalf of the Branch.

MR. R. HAFNER (*Fellow*, Chairman of the Bristol Branch), seconding the vote of thanks: Assuredly they had had a profound lesson in history. He had not had the opportunity to read the advance copy and the impact of the views coming direct from the lecturers had been tremendous. There were three kinds of papers of importance. In chronological order they were those that made history in the first instance, those that changed the shape of history and those that established the final shape of history. This paper had been one of the last type. They were very grateful indeed to the lecturers for the remarkable contribution they had made to the archives of aeronautical endeavour.

MR. E. T. JONES (*Fellow*): He did not think it would be at all fitting if they finished the proceedings there. Laurence Pritchard had devoted much of his time since he had retired, that was from 1951, to delving into the history of aeronautics and in particular to the history of the Aeronautical Society itself and during that time he had acquired a lot of knowledge and they would all benefit from it in years to come.

CAPTAIN J. LAURENCE PRITCHARD (*Hon. Fellow*): He would like to say that for anything which had been said that night in the lecture, he was wholly responsible. In the summary some of them might have felt that he had been a little hard on John Stringfellow. He hoped they would read the published lecture carefully because a summary often gave a wrong impression.

What this paper was really meant to do was first of all to bring forward much new evidence, all given in the lecture itself; but further than that, in the great hope indeed that more evidence still would come forward, because Stringfellow's reputation did not rest upon flying a little model in 1848. Stringfellow was a great man in many ways. He was, for example, one who took a deep interest in, and lectured upon, electricity. He corresponded with many of the leading electrical people of his time; and produced a galvanic battery which might cure anything from lumbago to rheumatism. Stringfellow was a man of wide knowledge and all that needed to be stated. His contemporary family left little record and he was quite sure that the surviving members of the family must have all kinds of memories left of what had been said in the family if they would only put them on paper or dig round and find things. He knew that some members of the family were present and he felt a bit nervous of what he had had to say about their great-great-grandfather, but he hoped very much that they would come forward and bring any fresh evidence, for if one were going to sum up a man's abilities one way or the other, one wanted as much evidence as possible. He had got what he thought was about 90 per cent. of it, but the other 10 per cent. might be more important and he hoped that some effort would be made, not to find, as had been the case up to this present time, that Chard had been boasting about one great man; the town now had the chance to boast about two great men. There were few towns like Chard that could boast about two great men. It had a right to be proud of both William Samuel Henson and John Stringfellow.

MR. E. T. JONES: They had had a very interesting evening and he would like to congratulate the lecturers himself. A paper of this kind did not take a long time to read, but it must have taken a great deal of time to prepare and see that the facts were right. In fact, a historical paper took longer to write than a paper on a scientific investigation or on a series of experiments.

An Engineering Approach to Some Structural Problems Arising from Kinetic Heating

by

E. H. BATEMAN, M.A., B.Sc., Ph.D., A.F.R.Ae.S.

(Royal Aircraft Establishment)

1. Introduction

The prospect of sustained supersonic flight has, in recent years, greatly stimulated research on the many problems involving temperature and heat transfer which must be solved before this prospect becomes a reality. Aerodynamicists have been investigating the nature and intensity of the heat loading. Metallurgists have intensified their research on the properties of conventional materials, and they have been joined by physicists, chemists, and engineers in the quest for new materials of construction. Research on relevant structural problems has begun with a number of theoretical and experimental studies of structural components under thermal loading, and laboratories are now being prepared for the full-scale simulation of the thermal conditions predicted in supersonic flight. Some details of this latest activity have been communicated to the Society by P. B. Walker[1] in a broad survey characterised by the following opening sentence: "The structural problems introduced by the kinetic heating of high speed aircraft require a radical extension of what has hitherto been regarded as the normal domain of structural theory."

This extension of the normal domain is of most consequence to the aircraft designer, who cannot, like a research scientist, concentrate on a particular aspect of the problem. The designer's task is to assess the actions to which his structure will be exposed, to select the most suitable materials, and to make the best use of them in the light of all the information made available by specialist research. The methods of research cannot be applied directly in design, although research results, the fruits of the work of aerodynamicists, metallurgists, and structural investigators, are a necessary prelude.

Hitherto the capacity of an aircraft designer to make sound decisions has depended on his knowledge of material properties and on his ability to anticipate the behaviour of his structure in terms of strength, stiffness, load diffusion, resilience, inertia, and other relevant factors. Now, before he can devise satisfactory solutions to kinetic heating problems, he must enlarge his engineering sensibility by cultivating an instinctive appreciation of the processes of heat transfer and its effects on different types of structures. In addition to being able to think and feel in terms of ductility, fatigue-resistance, crack-susceptibility, elastic and plastic stability, he must develop a practical sense of the significance of convection, conductivity, radiation, specific heat, diffusivity and thermal expansion.

Received 9th January 1956

It is against this background that the following notes are intended, in practical rather than scientific terms, as an introduction to some of the structural problems arising from kinetic heating.

Notation

b	thickness of plate or sheet
B.H.S.	British Heat System of Units
B.Th.U.	British thermal unit
C	specific heat, or Celsius according to context
C.G.S.	Centimetre Gramme Second units
E	Young's modulus
h	heat transfer coefficient
h_0	outer, or kinetic, surface transfer coefficient
h_i	inner surface transfer coefficient
h_c	conductive transfer coefficient
h_r	radiation transfer coefficient
K	thermal conductivity
M	Mach number
q	heat flux
R	thermal resistance
V	temperature potential
α	coefficient of thermal expansion, linear
θ_0	outer surface temperature
θ_i	inner surface temperature
θ_s	skin temperature

2. The Nature and Intensity of the Heat Loading

Kinetic heating was represented to aeronautical engineers less than five years ago by N. J. Hoff[2], in his notable paper to the Third Anglo-American Conference, as producing heat intensities, temperatures and stresses so alarming that the prospect of sustained flight at a Mach number of 4 seemed very remote. More recently, C. H. McLellan's demonstration[3] of the effectively instantaneous melting of Wood's metal in a blow-down jet at $M = 6{\cdot}9$ has apparently given practical verification of these alarming predictions. On the other hand, plans have recently been announced for the launching of satellite vehicles with a velocity relative to the earth's surface which corresponds, approximately, to $M = 25$ at sea level. The spectrum of kinetic heating intensities is therefore bounded on the one hand by the trajectories of ballistic re-entry, with the heat input measured in megawatts per square foot, and on the other by satellite orbits with necessarily tolerable equilibrium temperatures. Between these limits the severity of the heat loading will depend on altitude as well as speed, so

that the problem of supersonic aircraft design is not so much that of meeting a particular specification, arbitrarily imposed, as of finding the flight path which will give the most efficient solution for any particular schedule of surface to surface transport or ground-to-air interception.

The effect of kinetic heating is sometimes represented as the production of a temperature in the aircraft skin, approximating to the stagnation temperature or to the zero heat transfer temperature. Indeed, material properties are frequently expressed in terms of a particular Mach number loosely equated to temperature. Such simple assumptions and comparisons may be misleading. The zero heat transfer temperature cannot be reached in practice owing to the dependence of heat transfer on a potential difference in temperature. If there is no potential there can be no heat flow. The attainment of zero heat transfer temperatures at the outer surface of the skin would require either ideal insulation or complete saturation of the aircraft and its contents at the temperature of the external source. Ideal insulation is unattainable, for the reasons reviewed briefly in Section 5, and complete saturation is obviously unacceptable at any temperature level at which kinetic heating effects are serious.

The heat source is not simply an external temperature, but a temperature coupled with a transfer coefficient. The difference between the source temperature and the surface temperature is the temperature potential, and the product

$$\text{potential} \times \text{transfer coefficient}$$

determines the heat input, just as in an electrical circuit the current is the product of potential and conductivity. The compilation of data on the heat source, particularly the determination of heat transfer coefficients and methods for predicting numerical values, has for some time been a major pre-occupation of aerodynamicists, and R. J. Monaghan[4] has recently given a concise and useful introduction to this work.

Of the two components of the heat source, the temperature is the more easily expressed as a tangible loading parameter. A stagnation temperature is defined in terms of a kinetic temperature rise that is directly proportional to the square of the speed. An adiabatic wall temperature, or zero heat transfer temperature, lower than the stagnation temperature is then derived which takes account of the necessity for a zero temperature gradient in the boundary layer adjacent to the surface. A still lower value is assigned to the equilibrium wall temperature which includes outward radiation from the surface. The transfer coefficient is rather more elusive, in that it varies with the temperature potential as well as with the relevant aerodynamic characteristics, such as body shape, Reynolds number and other parameters.

The structures designer, in his assumption of a heat source, must ignore some of the refinements and reservations of the aerodynamicist, but in so doing he is possibly making approximations no more gross than those of the aerodynamicist computing transfer coefficients for homogeneous shells or solid sections of simple geometrical form, which are but ideal representations of an actual structure. The temperature component of the heat source may properly be taken as the equilibrium temperature, since this is an upper limit, provided that, if the computed skin temperatures are much below the equilibrium temperature, the allowance for outward radiation must be reduced on proceeding to a second approximation. In adopting values of the transfer coefficient for estimating heat flow in the structure, two simplifications may fairly be made; first, that the coefficient is independent of the temperature potential and, second, that topographical variations are not significant except in the immediate vicinity of a leading edge. The first of these assumptions is unlikely to lead to serious error and the second is justified by the fact that the transfer coefficient varies inversely as the fifth root of distance from the nose or a leading edge, so that for a ratio of distance of 10 to 1, the transfer coefficient only changes in the ratio 5 to 8.

Errors in estimating the magnitude of the heat source, which might be unacceptable in another context, appear relatively trivial if it is recalled that Hoff[2], in 1951, used a coefficient of 90, in British heat units, in an example of supersonic flight covering the range $M=1{\cdot}2$ to $M=3{\cdot}1$, while Monaghan[4], in 1954, assigns to the same parameter values of 15 at 50,000 ft., and 6 at 75,000 ft., for an aircraft body at $M=2{\cdot}5$ for a turbulent boundary layer, with values of 17 and 7 at $M=4$. In the same example, the estimated equilibrium temperatures given by Monaghan for the turbulent boundary layer at $M=4$ are 433°C. (max.) at 50,000 ft., and 354°C. (max.) at 75,000 ft., corresponding to a zero heat transfer temperature of 536°C. and a stagnation temperature of over 600°C.

These numerical assessments of the heat source cited from two of the leading authorities on kinetic heating, one in the field of structures and the other of aerodynamics, would perhaps not be irreconcilable if all the conditions associated with Hoff's assumption were set out in detail. But the comparison clearly exposes the absurdity of attempting to define a heat source solely in terms of Mach number or even of temperature. It also points to the need for obtaining full scale direct evidence of the magnitude of the heat source by measurement of the equilibrium temperature and the heat transfer coefficients in supersonic flight by aircraft designed for kinetic heating research.

3. Thermal Properties of Structural Materials

The basic thermal properties governing the flow of heat in a solid material are capacity, or specific heat, C, and conductivity, K. In steady state transfer, the only significant thermal property is conductivity. The effect of heat transfer in producing stress and distortion depends on the thermal stress modulus $E\alpha$, the product of Young's modulus and the coefficient of linear expansion.

In any one material the thermal properties vary with temperature, but the greatest variation is found in conductivity. Thus as R. C. Powell[5], for example, has shown, the conductivity of commercially pure iron drops

from 0·17 (C.G.S.) at room temperature of 0·09 at 600°C., whereas 25/20 Cr-Ni stainless steel rises from 0·03 to 0·05 over the same range. One consequence of this variation is that published solutions of problems in heat diffusion and thermal stress, based on the conventional value of 0·13, the conductivity of mild steel, cannot be applied without special interpretation to another steel with three times the thermal resistance. It is not generally practicable, in an engineering investigation, to take account of the variation of physical and thermal properties with temperature, although this has sometimes been done, as in the problem of the thick cylinder investigated by C. H. McKoen [6], who used a value of E dependent on temperature. For the purpose of estimating the nature and effects of heat transfer in an aircraft structure it is reasonable to take mean values appropriate to the expected temperature range.

Much more significant than variations with temperature in a particular material are the variations in thermal properties from one material to another. Considering the three principal metals available for airframe construction, the following comparisons are of interest. A typical aluminium alloy has a conductivity 8 or 10 times that of either titanium or stainless steel. High conductivity promotes rapid heat diffusion, thermal equilibrium and low thermal stress, so that aluminium has an undoubted advantage over other metals up to the temperature levels at which its constructional properties begin to deteriorate significantly.

The thermal stress modulus is an important parameter. Approximate values for aluminium, titanium and stainless steel are 240, 135 and 360 lb./in.^{2} per degree C. This comparison does not fully represent the difference between aluminium and titanium, or stainless steel, because the thermal stress modulus is simply the key to thermal stress when the temperature distribution has been determined, and the temperature gradients for a given heat loading will be much lower with aluminium. On the other hand, since titanium and stainless steel have conductivities of the same order of magnitude, much lower stresses will be experienced with titanium than with stainless steel for a given heat loading. Titanium, by reason of its low coefficient of expansion and low modulus of elasticity, shows an outstanding advantage over stainless steel for all applications where high temperature gradients are unavoidable. In conditions of transient transfer, the lower density and proportionately higher diffusivity of titanium lead to a figure of merit for titanium roughly five times that of stainless steel.

4. Comparison of Heat Transfer by Different Modes

In every practical problem of heat transfer, each of the three modes, convection, radiation, and conduction, makes some contribution, and it is therefore necessary to be able to compare the effectiveness of one mode with another. For this purpose some writers, B. C. Bosworth [7], for example, have defined a conductive transfer coefficient h_c, and a radiation coefficient h_r, which can be compared directly with the surface transfer coefficient h. Thus, the conductive transfer coefficient across the thickness of a sheet is the conductivity divided by the thickness, *i.e.*

$$h_c = K/b \quad . \quad . \quad . \quad (1)$$

and the radiation transfer coefficient is the radiation flux divided by the temperature potential between the emitting and receiving surfaces, *i.e.*

$$h_r = q/V. \quad . \quad . \quad . \quad (2)$$

The concept of thermal resistance is useful in many problems of steady heat transfer, since there is a direct analogy with electrical resistance. Thermal resistance, the temperature potential divided by the heat flux, is the reciprocal of the transfer coefficient, and the basic equation of heat transfer in terms of resistance is

$$q = V/R \quad . \quad . \quad . \quad (3)$$

where q is the flux, V the temperature potential and R the resistance.

In a transfer of heat through several resistances in series

$$q = \frac{V_1}{R_1} = \frac{V_2}{R_2} = \ldots = \frac{V}{\Sigma R}. \quad . \quad (4)$$

where V is the overall temperature potential ΣV_1, and ΣR is the sum of the individual transfer resistances.

It follows at once from equation (4) that if one resistance, in a series transfer, is much less than any one of the others it makes no significant contribution to the overall resistance and can therefore be ignored at the outset. For example, when considering transfer through a thin metal sheet with convection in air on both surfaces, the resistance of the metal is negligible, and for practical purposes the flow of heat depends solely on the outer and inner air temperatures and surface transfer coefficients. The metal sheet is at a sensibly uniform temperature across its thickness, and a low-conductivity material, such as stainless steel or titanium offers no more effective heat barrier than aluminium.

Some values of the kinetic transfer coefficient have been mentioned in Section 2, ranging from 90 to 6, in the British system of heat units. These may be compared with the conventional value of unity for the transfer coefficient by natural convection in air, and that of 200 for natural convection in water. Conductive transfer coefficients for metal sheets less than a tenth of an inch thick exceed 1,000, in the case of steel and titanium, and exceed 10,000 in the case of aluminium.

The radiation transfer coefficient reaches a value of unity between 300 and 400°C., depending on the value of surface emissivity. The effect of radiation becomes important when source temperatures exceed 300°C., and it may become highly significant with higher source temperatures, coupled with the lower kinetic transfer coefficients predicted at high altitudes, that is in conditions in which the radiation transfer coefficient becomes comparable in magnitude with the kinetic transfer coefficient.

5. Thermal Insulation

Materials of low conductivity are known as insulators, although in this context the word insulation

has a very different meaning from that which it bears in the analogous field of electrical technology. Electrical engineers can call on a variety of materials of which the specific resistance lies in the range 10^{21} to unity, which in F. B. Pidduck's hypothetical illustration[8] is "the ratio in which the current divides if a copper wire and an ebonite 'wire' of the same size are connected in parallel." There is, unfortunately, nothing in the province of heat transfer remotely approaching this disparity, excepting possibly very low temperature high vacuum techniques. For solid materials the corresponding thermal range is little more than a thousand to one. This at first sight might appear to be a ratio that should not be contemptuously dismissed, merely because the corresponding electrical one is so high. But, in the field of kinetic heating, the relevant comparison is not so much that of one material with another but of the conductive transfer coefficient of a sheet of insulating material with the kinetic transfer coefficient.

An obvious requirement is to reduce the heat flow into the structure. If efficient exterior insulation were available, not only would the heat input be kept low but the whole of the structure maintained at a moderate temperature. A typical structural insulator is vacuum Durestos with a conductivity of 1·5 (B.H.S.). This means that its thermal resistance is nearly a thousand times that of aluminium, but the conductivity transfer coefficient of a sheet of this Durestos a quarter of an inch thick is almost the same as the kinetic transfer coefficient predicted by Monaghan[4] for an aircraft body flying between $M=2{\cdot}5$ and $M=4$ at 75,000 ft. To be effective, the insulating layer should have a resistance considerably greater than the reciprocal of the kinetic transfer coefficient. Internal insulation shows a brighter prospect of keeping out the heat, since low density foamed plastics, with a conductivity of about 0·5, can be used in greater thicknesses than could be tolerated for external insulation. The disadvantage of internal insulation is that it reduces the difference between the equilibrium temperature and the skin temperature, with a higher effective skin temperature and steeper temperature gradients.

The possibility of alleviating transient stresses by the use of surface insulation has been examined by E. W. Parkes[9], who considered the case of a thick metallic skin protected by a thin layer of insulation of negligible heat capacity. Parkes determined the maximum temperature difference between the outer and inner surfaces of the metal skin and his solution shows that insulation is the more effective when the kinetic transfer coefficient is high.

Although insulation cannot be used to annul the penetration of heat into a structure, it may have useful applications in reducing the input of heat and avoiding peak intensities of temperature and stress. Insulation can only have a transient effect, unless provision is made for internal cooling.

6. Transient Effects

In every problem of heat transfer there is a transient phase covering the period between a change in intensity of the heat source and attainment of the steady state. The importance of the transient phase in some problems of aircraft design has been emphasised by N. J. Hoff[2] and E. W. Parkes[10], in analytical investigations of an aerodynamically thin wing of multi-cellular construction. For the investigation of such problems it may sometimes be necessary, as Parkes[9,10] has shown, to apply the partial differential and integral equations formulated by Fourier and Duhamel, and to obtain solutions by the mathematical methods of the Laplace transform and Mellin's inversion theorem. Such methods are complicated and tedious, while iterative or relaxation processes for the evaluation of numerical results are almost as formidable, with the consequence that the word transient has virtually become an epithet of menace in this context.

Fortunately, however, it is not always necessary to use rigorous analytical methods for the estimation of transient effects. There is, for example, no transient problem of any practical substance in the heating of a skin plate, so long as the conductive resistance of the plate is only a fraction of the kinetic transfer coefficient. Thus, the conductive transfer coefficient of a stainless steel plate one inch thick is about 100 in the British system of heat units, so that for kinetic transfer coefficients of 10 or less, of the order of magnitude associated with high altitude flight, the resistance of the plate is not more than a tenth of the surface transfer resistance, and the flow of heat into the plate can be estimated with reasonable accuracy by steady state methods.

For plates which can be regarded as thin, in the sense of having a relatively low transfer resistance, the time taken for a proportionate temperature rise, on sudden exposure to a heat source, depends only on the specific heat and density of the material. If the interior surface is assumed to be effectively insulated, so that all the heat entering the plate is retained, the time in hours for a temperature rise of 65 per cent. of the applied temperature potential is approximately:

$4{\cdot}5\ b/h$ for steels, and

$3\ b/h$ for aluminium and titanium alloys,

where b is the plate thickness in inches and h is the kinetic transfer coefficient in British Thermal Units per square foot per hour per degree Fahrenheit. The times for temperature rises of 87 and 95 per cent. of the applied potential are twice and three times as long.

For a structurally thin plate, say 0·05 in. thick, the duration of the transient phase would therefore not be more than a few minutes even with low values of the kinetic transfer coefficient. Yet, in some applications, a few minutes may be a significant period of time, long enough perhaps to establish an international air speed record, to gain real experience of the aerodynamic loading coefficients, and to explore the topographical distribution of the heat source.

On the other hand, the thicker plates which may be necessary for wings and control surfaces with very low ratios of thickness to chord will react sluggishly to high source temperatures, if the kinetic transfer coefficient is low, and the time required to approach the equilibrium

temperature may frequently be found to exceed the endurance required for operational aircraft.

7. Steady Flow Through a Thin Skin

In the preceding section, estimates of the time required to raise the temperature of a thin skin have been based on the hypothesis of an effectively insulated interior surface. This is a reasonable assumption for the purpose of defining the duration of the transient phase. It cannot now be applied to obtain estimates of steady state conditions, since it leads to a zero value of the heat input with the structure and its contents soaked at the heat source temperature. In the steady state the action at the inner surface has a more decisive effect than that on the outer.

Accordingly an inner surface transfer coefficient h_i is introduced, and the kinetic transfer coefficient applicable to the outer surface is now denoted h_0. If the inner and outer source temperatures are θ_i, θ_0 and the skin temperature is θ_s, the identity of heat flux at the inner and outer surfaces, which is easily written down by using equation (4), leads at once to the relation

$$\theta_s=\theta_0-\frac{h_i}{h_0+h_i}(\theta_0-\theta_i) \quad . \quad . \quad (5)$$

for the temperature of a metal skin of low conductive resistance.

Since h_i cannot be zero, which is the value denoting perfect interior surface insulation, the skin temperature will always be less than the source temperature. If h_i is large, as for liquid cooling on the inner surface, the skin temperature will generally be much closer to the inner than the outer source temperature. In the more usual case when h_i has a value near unity, which corresponds to natural convection in air, a value which might be increased to 2 or more by internal radiation, or reduced to 0·5 or less by interior surface insulation, the relation of the skin temperature to the source temperature will depend very largely on the magnitude of the kinetic transfer coefficient h_0.

With a high value of the kinetic transfer coefficient, for example $h_0=90$, the difference between source and skin temperatures would not be more than a few degrees, but with values less than 10, such as are expected at high altitudes, the skin temperature may be considerably below the source temperature. To illustrate this point, reference is again made to Monaghan's estimate[4] of the conditions which may be expected in flight at $M=4$ at 75,000 ft., *i.e.* a kinetic transfer coefficient of 7 and a maximum equilibrium temperature of 354°C., in turbulent flow, without loss of heat to the interior. Thus $\theta_0=354$, $h_0=7$, and, assuming an internal source temperature of 20°C. with a transfer coefficient of 2 which is representative of natural convection and radiation, the skin temperature computed from equation (5) would be 280°C., although the stagnation temperature is over 600°C.

The rate of flow of heat into the body of the aircraft in the steady state is

$$q=V/\Sigma R \quad . \quad . \quad . \quad (6)$$

where V is the temperature potential in degrees Fahrenheit, and ΣR is the total thermal resistance. With an uninsulated thin metal skin $R=(1/h_0+1/h_i)$, so that for the above example

$$q=1{\cdot}8\times 334/(0{\cdot}14+0{\cdot}5)$$
$$=940 \text{ B.Th.U. per sq. ft. per hour}$$
$$=0{\cdot}28 \text{ kW. per sq. ft.}$$

This input could be reduced to 0·07 kW. per sq. ft. by insulating the interior surface with a one-inch layer of material having a conductivity of 0·5 B.Th.U. per sq. ft. per hour per degree Fahrenheit per inch, but the skin temperature would rise to 336°C.

Such estimates of skin temperature, founded on an egg-shell theory of construction, constitute only a first approximation to the analysis of a stiffened sheet supported on stringers and frames. Skin temperatures will be reduced near junctions with stringers, but more important may be the cooling-fin effect of all structural members to which heat is fed in the plane of a thin sheet with convective loss from a comparatively large area. With stainless steel or titanium stiffeners, which have a relatively high thermal resistance in the plane if the metal is thin, the drop in temperature due to this effect may be large enough to permit the use of aluminium alloy for frames.

8. Conclusions

In these introductory notes, the problem of design of airframes for supersonic aircraft has been presented as one of development of current design practice, rather than as a novel problem demanding revolutionary treatment. The history of engineering design in many fields has shown that radical changes only ensue when contemporary conventional methods have been fully exploited, and that the necessity for considering radical changes does not normally arise until the limits of development of conventional systems can be foreseen. Over ten years ago, predictions of high external temperatures in supersonic flight prompted research on materials to replace aluminium as the primary material for aircraft construction. One important result of the foresight of the authorities formerly responsible for research and development is the forthcoming availability of titanium alloys with nearly double the specific strength of stainless steel and very favourable thermal properties.

Estimates of the steady temperatures, and the related heat input for an aircraft body in sustained flight at $M=4$ at 75,000 ft., based on Monaghan's predictions of maximum equilibrium temperature and kinetic transfer coefficients, show that internal cooling by natural convection may have an appreciable effect in reducing structure temperatures at high supersonic speeds at high altitude. These estimates give *prima-facie* justification for the proposition that the usefulness of titanium and aluminium as constructional materials cannot be assessed by the simple equation of adiabatic wall temperature to the limiting temperature of material serviceability. In the light of knowledge at present available it

is not possible to define, in terms of operational performance, all the conditions in which aluminium and titanium will have no place in airframe construction.

More exact estimates cannot be made on the evidence of heat transfer coefficients and thermal resistances derived in other contexts, and the immediate need in the laboratory is for accurate determination of basic heat transfer data for direct application to aircraft design. What, for example, will be the temperature of an aircraft skin when the interior of the fuselage is maintained at room temperature by low velocity forced convection? Or, what is the temperature in the upper skin of an integral fuel tank exposed to kinetic heating on one surface and fuel vapour on the other? To these and many other similar questions of practical importance, the answers obtainable by adopting heat transfer data from engineers' handbooks must be of doubtful validity. There is scope here for a research effort on a scale comparable, for example, with the investigation by metallurgists of the properties of materials at elevated temperatures.

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Air Transport Course

Christ Church, Oxford 4th—18th April 1956

AT THE beginning of the year the Council of the Society were requested by Mr. H. E. Marking, Secretary of British European Airways, and Mr. S. N. Grant-Bailey, Dean of the Faculty of Law, University of Southampton, to consider the Sponsorship of a Course on Air Transport to be run at Christ Church, Oxford, immediately after Easter.

Council agreed to arrange such a course provided that the response was adequate.

A brochure was prepared and distributed to the airline companies and to the aircraft firms likely to be interested in the Course, which, to quote the brochure, was " intended for the junior executives of firms, say 25 to 35 years old, who can be expected to fill, in the future, positions of wider scope." Admission to the Course was not limited to the employees of airline operators or aircraft manufacturers, but was open to other applicants.

The brochure was distributed in February and the first reservation came within a few days from Iceland Airways, provisional registration being made by cable for six students. By the time the Course started at Oxford on Wednesday, 4th April, thirty-four students had enrolled. In addition to those who had enrolled, many airline operators had shown their interest, but were unable to send any students, due to the short notice which had been given. All said they wished to be informed of developments, and requested details of future courses.

Representatives were sent by the Aircraft Industry, the Airline Operators, the Oil Companies, and one came from the academic world of the London School of Economics.

Armstrong Whitworths, Blackburns, Bristols, Handley Page, Rolls-Royce, Short Brothers and Harland, and Vickers'-Armstrongs sent students, as did Shell and British Petroleum. The Airline Operators represented were Aer Lingus, Airwork, Air Vietnam, British European Airways, Greek Airways, Hunting Clan, Iceland Airways, Israel Airways, K.L.M., Pan American Airways, and Skyways.

During the afternoon of 4th April the students arrived at Christ Church, were allocated to rooms, and given the information concerning lectures and discussion groups. By teatime all but one or two had arrived, and they assembled in the Junior Common Room for tea. They were welcomed by Dr. A. M. Ballantyne, the Director of the Course and Secretary of the Society, and he introduced them to Dr. E. W. C. Wilkins, the Assistant Director, and to the Lecturers, Mr. A. R. Barrowclough (Air Law), Mr. S. F. Wheatcroft (Economics), and Mr. K. G. Wilkinson (Operations). Mr. N. E. Rowe, the President of the Society, then spoke a few words. He explained how it came about that the Society had arranged this Course at the request of Mr. Marking and Mr. Grant-Bailey, and the response had demonstrated that there was a need for this Course. He hoped that they would derive full benefit from it. Mr. Rowe also expressed his pleasure at seeing both the operators and the aircraft industry represented, for he was sure that the benefits arising from the intimate discussions in the confines of Christ Church would be mutual.

The President then introduced to the students Lord Brabazon of Tara, a figure of international reputation and fame. That the presence of Lord Brabazon was appreciated was shown by the handclaps which followed the introduction. Lord Brabazon spoke of the past and the future, and hoped that in the days to come his hearers would be the executives in the top flight of the operators.

The students quickly settled in and speedily became acquainted with their scheme of work and their lecturers.

During the Course three subjects were taught, Air Law by Mr. A. R. Barrowclough, B.A., Economics by Mr. S. F. Wheatcroft, B.Sc. (Econ.), and Operations by Mr. K. G. Wilkinson, B.Sc., A.F.R.Ae.S.

Mr. Barrowclough, Barrister-at-Law of the Inner Temple, was educated at Stowe and New College, Oxford, where he took a First Class Honours Degree in the School of Jurisprudence and was awarded an Elden Law Scholarship. He is joint author of the Section on " Civil Aviation " in Halsbury's " Laws of England " (Third Edition).

Mr. S. F. Wheatcroft obtained in 1942 a First Class Honours Degree in Economics at the London School of Economics. After the 1939-45 War, in which he served as a Pilot in the Fleet Air Arm, he returned to the London School of Economics with a Leverhulme Post-Graduate Studentship to study, in particular, the Economics of Air Transport. Mr. Wheatcroft was appointed Economic Adviser to British European Airways in 1946, and subsequently joined the Commercial Department as Manager in charge of Research and Tariffs. He left B.E.A. in 1953, going to the University of Manchester as a Simon Research Fellow. He has

written a book entitled "The Economics of European Air Transport." This was published in April of this year. In 1954 he was appointed Economic Planning Consultant to British European Airways.

Mr. K. G. Wilkinson graduated in Mechanical Engineering, with First Class Honours, in 1937, and he took a post-graduate degree in Aeronautics at Imperial College. During the 1939-45 War he worked at the Royal Aircraft Establishment at Farnborough in the Aerodynamics Flight Research Section, being in charge of a special unit which developed military gliders and equipment for the airborne forces. He also flew as a pilot during this period, and he is a member of the Caterpillar Club. During his first six years with British European Airways he was a Superintendent in the Project and Development Branch, in charge of the Performance and Analysis Section. Since then he has been the Manager in charge of Schedule Planning. Mr. Wilkinson has become, this year, a Fellow of the Society.

The students were divided into three groups in accordance with the type of job each student held, so that the experience throughout each group would be as wide as possible. These groups remained throughout the course, without alteration, and within the groups were held the various discussions and case studies.

Ten lectures were given in each of the three subjects, Air Law, Economics and Operations, and these were supplemented by discussions and case studies. A detailed programme is given in the Appendix II. In the Operations Series lectures were also given by Professor E. J. Richards (University of Southampton), Wing Commander G. M. Macintosh, Deputy Director of Control and Navigation, Ministry of Civil Aviation, and Mr. G. FitzGerald, Commercial Development Superintendent, Aer Lingus.

Most evenings, between tea and dinner, a guest speaker gave either a lecture or a talk to the students. This was followed by a discussion.

The speakers, and their subjects, were as follows:—

(1) Mr. Bo Björkman, Secretary General, Air Research Bureau, Brussels.
"Prospects for the Future Development of Air Traffic."

(2) Mr. R. A. C. Brie, B.E.A. Helicopter Experimental Unit.
"The Future of the Helicopter."

(3) Mr. B. S. Shenstone, Chief Engineer, B.E.A.
A general talk on Operations, with emphasis on Engineering.

(4) Mr. V. de Boursac, Secretary, Traffic Conference 2, I.A.T.A.
"The Work and Scope of I.A.T.A."

(5) Mr. H. Bouché, the Representative of France on I.C.A.O.
A general talk on Air Transport Management and the work of National and International Organisations.

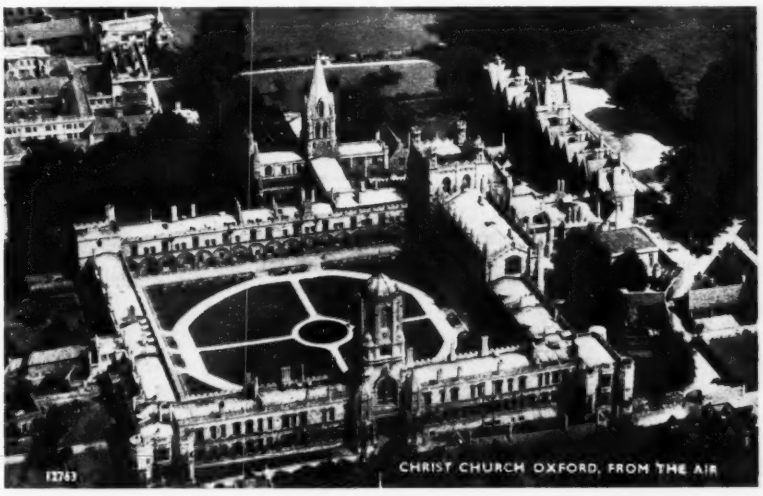
(6) Professor Dr. D. Goedhuis, Civil Air Attaché, Royal Netherlands Embassy, London.
"Politics and Law in International Civil Aviation."

(7) Mr. C. Shawcross, Q.C.
"The General Principles of Air Law."

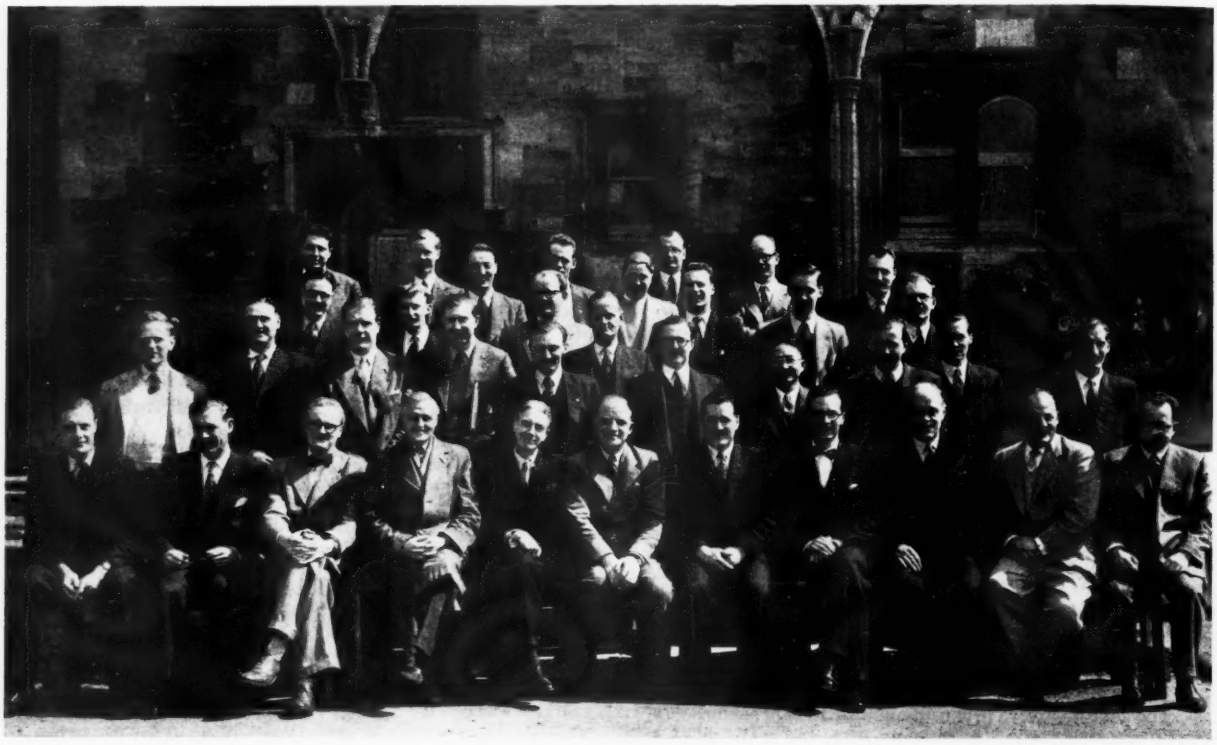
Details of the Syllabuses for each of the three subjects are set out in Appendix I.

On the afternoon of Wednesday, 11th April, the students visited the Bristol Aircraft Company at Filton, where they were welcomed by Mr. Peter Masefield, who, in the course of his remarks, told them something of the programme for the production of the Britannia.

At the end of his address Mr. Masefield announced that a flight in a Britannia had been arranged for them, and soon they were flying at 20,000 feet. All the students showed keen interest in the lay-out of the



An aerial view of Christ Church, Oxford, where the Society's first Air Transport Course was held.



The Air Transport Course—A photograph taken at Christ Church, Oxford, of the Lecturers and all but three of the 34 Students. The officials of the Course are in the front row, from left to right, A. R. Barrowclough, S. F. Wheatcroft, K. G. Wilkinson, Dr. E. W. C. Wilkins and Dr. A. M. Ballantyne.

aircraft, and wandered around, trying this and that, and asking innumerable questions on accommodation and performance. After about three quarters of an hour the Britannia landed smoothly at Filton. It was only possible for a quick tour of the assembly hangar, before the students set out on their return trip to Oxford.

The Course was visited by a number of interested people, one of whom was Sir Frederick Handley Page, who, after dinner, gave the students a talk which ranged far beyond cabbages and kings and "ceiling" wax.

On Tuesday, 17th April, Mr. P. G. Masefield paid a welcome return visit to the Course, landing by helicopter on the sports field of Christ Church. After lunch Mr. Masefield gave a short talk to appreciative students and guests.

The Course finished at lunch time on Wednesday, 18th April, and to celebrate its closing a Guest Dinner was held in the Hall at Christ Church on the previous evening. Among the guests were members of the Council of the Society, representatives of the University of Oxford, the Law and Airline Operators, and of the Press. The President, from the Chair, proposed the toast to Air Transport, the reply being given by Sir Frederick Tymms, formerly the United Kingdom representative on the Council of I.C.A.O. The toast to the Guests was given by the Director of the Course, Dr. A. M. Ballantyne, and he paid tribute to Dr. Wilkins, the Assistant Director, and to the resident lecturers, Messrs. Barrowclough, Wheatcroft and Wilkinson. He stressed the ever-ready and willing co-operation of the Officers of Christ Church, especially Lt. Col. D. V. Hill, and he gave special thanks to Mr. Marking and Mr. Grant-Bailey, who had first suggested the Course. Mr. Grant-Bailey, in his reply, expressed his personal gratification at the success of the Course, with the hope that the Society would hold it annually until a Department of Air Transport had been inaugurated at the University of Oxford, and to this department would be given the opportunity of holding the Course.

Before the Dinner ended a representative of the students made a few remarks of appreciation, and a presentation was made to the lecturers and Mr. Grant-Bailey, to show their appreciation and satisfaction at the success of this first Air Transport Course, held by the Society.

The following morning the Director and the Lecturers held a brief discussion on the answers to a questionnaire which had been circulated previously. Many helpful suggestions were brought forward, especially concerning the length of the Course and the size of the discussion groups.

There is little doubt that there is a need for such a

Course on Air Transport, for every student was certain that he had derived much useful knowledge, which would be of great benefit to him in his future activities. The representatives of the aircraft industry were no less enthusiastic concerning the benefits which they were certain would be felt by them also, for it was useful to know about the operation of the aircraft which they were building.

The Council of the Society have under consideration the question of holding a second course during Easter 1957 and an announcement will be made concerning this in the near future.

APPENDIX I

THE COURSE OF STUDY

I. Economics of Air Transport

The economic function and service of national and international air transport. The economic significance of speed in trade, travel and communications.

The economics of the aeroplane:—capital cost, obsolescence and depreciation, aircraft insurance, the importance of utilisation, the effect on costs of speed, size, stage length, load factor, etc.; crew costs (including expenses, pensions and insurance), composition of crew, conditions of service, etc.

The economics of airline operations:—capital requirements, types of ownership, general organisation, optimum size; analysis of revenue; turnover of capital; analysis of expenditure, fixed annual costs, hourly cruising costs, landing costs; effect on costs of frequency, intensity of operation, pattern of services, seasonal traffic variation; factors affecting the supply of labour and remuneration of employees.

Commercial policy:—the principles of fixing fares and rates, relationship with costs, the importance of joint costs, competition, discriminating monopoly, etc.; the standards of passenger accommodation and cargo service in relation to fares and rates; air mail rates, inter-airline agency agreements, pooling systems; sales agency agreements and commissions.

National and international economic regulations:—the justification for regulation, licensing of operators, control of capacity and tariffs; the effect of international agreements on capacity and tariffs; the role of the International Air Transport Association, conference system and agreements on tariffs; the history and practice of State assistance to air transport.

Airport and airways economics:—capital requirements for airports and air traffic control, types of ownership; analysis of revenue, methods of assessing landing fees and other charges; analysis of expenditure, relationship between revenue and expenditure; State assistance.

Economics of non-scheduled air services:—relation between charters and regular services; principles of fixing charter rates, relationships with costs, working of the Baltic Exchange air market.

II. Air Transport Operation

The organisation of air transport undertakings and the structure of the main departments; the duties and responsibilities of ground and flying staff—engagement, training, licensing, control, working conditions.

National and international technical regulations; air traffic control and services; instrument approach and navigation aids; meteorological, signalling and communication facilities.

International traffic regulations; principles and effects of international bilateral agreements; customs, immigration and medical formalities.

Location, design, lay-out and working of airports; design of hangars, workshops and airport equipment, refuelling and turn-round arrangements.

Routes and services; designing of time-tables; rostering of aircraft and crews; operation of charter services.

Classes and types of aircraft and their flying characteristics; capacities, speeds, and ranges; types of propulsive units; types of fuel and fuel systems; international lay-out; air conditioning and pressurisation; methods of overhaul and inspection; recent trends in design and construction.

Load controls and bookings; loading of aircraft; aircraft papers and documentation; handling of passengers, mail and freight; customs clearance and delivery of freight; special services for freight; documentation for charters.

Organisation of stores, supplies and spares.

Sales and publicity; commercial research and development; the use of statistics.

III. Air Law

Development and Sources of International Air Law; International Conventions.

"Right to Fly." Chicago Convention; International Bilateral Agreements; Route Licensing.

Nationality and Registration of Aircraft. Conflict between Systems of National Law.

Private Rights and Liabilities arising out of Carriage by Air. The Warsaw Convention:—

General Principles.

Passengers.

Baggage and Cargo.

Private Rights and liabilities in connection with the use of Air space in the operation of aircraft; Rome Convention.

Private Rights and Dealings in Aircraft.

Law relating to the operation of Aircraft and Aerodromes; Annexes to the Chicago Convention.

Organisations concerned with International Air Law.

International Air Law in War and Emergency.

APPENDIX II

AIR TRANSPORT COURSE

Date	*Morning*	*Afternoon*	*Evening*
Wednesday 4th April		ASSEMBLE FOR TEA	5.30-6.30—Opening Remarks by Mr. N. E. Rowe, President ADDRESS by Lord Brabazon
Thursday 5th April	9.30-10.30—Lecture, Operations 10.30-11.30—Lecture, Law 11.30-12.00—Coffee Break 12.00-1.0 p.m.—Lecture, Economics	2.30-4.30—Discussion 3 groups of students to discuss each subject for 25 minutes among themselves under their own Chairman, the Chairman to be changed each time. Followed by a 45 minute discussion period all together with the lecturers 4.30—Tea	5.00-6.30—Guest Lecturer: Mr. Bo Bjorkman
Friday 6th April	9.30-10.30—Lecture, Operations 10.30-11.30—Lecture, Law 11.30-12.00—Coffee Break 12.00-1.0 p.m.—Case Study in Economics	2.30-3.30—Case Study in Operations 3.30-4.30—Lecture, Economics 4.30—Tea	5.00-6.30—Guest Lecturer: Mr. R. A. C. Brie
Saturday 7th April	9.30-10.30—Lecture, Operations 10.30-11.30—Lecture, Law 11.30-12.00—Coffee Break 12.00-1.0 p.m.—Lecture, Economics	FREE	FREE
Sunday 8th April	Cathedral Service	FREE	FREE
Monday 9th April	9.30-10.30—Lecture, Operations 10.30-1.0 p.m.—Discussions with Professor E. J. Richards 11.30-12.00—Coffee Break	2.30-4.30—Lectures (Law, Economics) 4.30—Tea	5.00-7.00—Case Study in Law Mr. B. S. Shenstone to dinner Talk by him after dinner
Tuesday 10th April	9.30-10.30—Lecture, Operations 10.30-1.0 p.m.—Discussions with Wing Cdr. Macintosh 11.30-12.00—Coffee Break	2.30-4.30—Lectures (Law, Economics) 4.30—Tea	5.00-6.30—Guest Lecturer: Mr. V. de Boursac
Wednesday 11th April	9.30-10.30—Lecture, Operations 10.30-11.30—Lecture, Law 11.30-12.00—Coffee Break 12.00-1.0 p.m.—Lecture, Economics	Visit to Bristol Aircraft Limited	FREE
Thursday 12th April	9.30-10.30—Lecture, Operations 10.30-11.30—Discussion with Mr. Bouché 11.30-12.00—Coffee Break 12.00-1.0 p.m.—Discussion with Mr. Bouché	2.30-3.30—Lecture, Law 3.30-4.30—Lecture, Economics 4.30—Tea	5.00-7.00—Lectures
Friday 13th April	9.30-10.30—Lecture, Operations 10.30-11.30—Lecture, Law 11.30-12.00—Coffee Break 12.00-1.0 p.m.—Case Study in Economics	2.30-3.30—Case Study Operations 3.30-4.30—Lecture, Economics	5.00-6.30—Guest Lecturer: Dr. D. Goedhuis
Saturday 14th April	9.15-1.0 p.m.—Discussions with Mr. G. FitzGerald 11.30-12.00—Coffee Break	FREE	FREE
Sunday 15th April	Cathedral Service	FREE	FREE
Monday 16th April	9.30-10.30—Lecture, Operations 10.30-11.30—Lecture, Law 11.30-12.00—Coffee Break 12.00-1.0 p.m.—Lecture, Economics	2.40-4.30—Review of Case Study in Operations with Lecturers	5.00-6.30—Guest Lecturer: Mr. Christopher Shawcross, Q.C. Review of Case Study in Law after Dinner
Tuesday 17th April	9.30-11.30—Discussion: Operations 40 mins. Law 40 mins. Economics 40 mins. 11.30-12.00—Coffee Break 12.00-1.0 p.m.—Discussion Mr. P. G. Masefield to lunch	3.0-5.0—Review of Case Study in Economics with Lecturers	Guest Dinner in Hall
Wednesday 18th April	9.30-11.30—General Discussion with questions 11.30-12.00—Coffee Break 12.00—Closing remarks (Dr. A. M. Ballantyne)		

TECHNICAL NOTES

Contributions to this Section of the JOURNAL *will be eligible for Journal Premium Awards and will normally be published within two months of being received.*

Asymmetric Heat Transfer to Gases in Turbulent Flow Between Parallel Plates

by

HENRY BARROW, M.Eng., A.M.I.N.A.

(*Mechanical Engineering Department, University of Liverpool*)

THE SIMPLEST case of asymmetric heating of a fluid flowing between parallel plates is considered. This occurs when heat is transferred to the fluid through one plate, the other being adiathermal. For a theoretical analysis, it is convenient to assume fully developed flow in a parallel channel of infinite aspect ratio, this condition being not widely different to that met with in practical applications. The problem dealt with is shown diagrammatically in Fig. 1.

NOTATION

c	specific heat at constant pressure
$D_e = 2p$	equivalent diameter ($4 \times$ flow area/wetted perimeter)
ε	eddy diffusivity of heat (and momentum)
h	heat transfer coefficient
k	thermal conductivity
p	plate spacing
q	specific heat flux
Pr	Prandtl number $= \frac{c\mu}{k}$
Nu	Nusselt number $= \frac{hD_e}{k}$
Re	Reynolds number $= \frac{\bar{u}D_e\rho}{\mu}$
u, $\bar{u}$	velocity, average velocity
y	wall distance
ρ	density
μ	viscosity
τ	shear stress
θ, $\Delta\theta$	temperature, axial temperature change in a distance x in flow direction
u^+	friction velocity parameter $= u/\sqrt{(\tau_w/\rho)}$
y^+	friction distance parameter $= y\sqrt{(\tau_w/\rho)}\,\rho/\mu$

Suffices

w	wall
b	bulk value
1	sub-layer—buffer layer boundary
2	buffer layer—turbulent region boundary
s	symmetrical heating

THEORY

For all fluids, the velocity distribution in the channel is

1. $u^+ = y^+$ in the laminar sub-layer, for $y^+ \leqslant 5$
2. $u^+ = -3{\cdot}05 + 5\log_e y^+$ in the " buffer " layer, for $5 \leqslant y^+ \leqslant 30$

and 3. $u^+ = 5{\cdot}5 + 2{\cdot}5\log_e y^+$ in the turbulent zone, for $y^+ > 30$.

For turbulent flow in rectangular channels, substitution of the conventional equivalent diameter ($4 \times$ flow area divided by the wetted perimeter) in the Blasius equation for smooth circular tubes satisfactorily correlates the experimental friction data for air and water. The conventional equivalent diameter for a passage of large aspect ratio approaches the value $2p$, when the wall friction is given

$$\tau_w = \frac{0{\cdot}079}{2}\,\frac{\rho\bar{u}^2}{\mathrm{Re}^{\frac{1}{4}}} \quad \text{where} \quad \mathrm{Re} = \frac{\bar{u}(2p)\,\rho}{\mu}.$$

The heat transfer coefficient is defined by the equation

$$\mathrm{Nu} = \frac{\mathrm{RePr}q_w}{c\rho\bar{u}(\theta_w - \theta_b)} \quad \text{where} \quad \mathrm{Nu} = \frac{h\,(2p)}{k}.$$

To obtain the Nusselt number Nu, the temperature drop $(\theta_w - \theta_b)$ may be determined by considering the sub-layer, buffer layer and turbulent regions separately. While the results of the present investigation can only be considered accurate for gases, all three zones are included for the sake of completeness. Conduction is the heat transfer mechanism in the laminar sub-layer when

$$q_w = \frac{k\,(\theta_w - \theta_1)}{y_1}.$$

Introducing

$$y_1^+ = 5,$$

the sub-layer temperature drop

$$(\theta_w - \theta_1) = \frac{q_w}{c\rho}\sqrt{\left(\frac{\rho}{\tau_w}\right)}5\mathrm{Pr}. \quad . \quad . \quad (1)$$

In the buffer layer, heat and momentum are transferred by the two mechanisms of molecular and molar exchange, and if the specific heat flux and shearing stress at the sub-layer-buffer layer boundary are nearly equal to the wall values, then

$$\frac{\tau_w}{\rho} = \left(\frac{\mu}{\rho} + \varepsilon\right)\frac{du}{dy} \quad . \quad . \quad . \quad (2)$$

$$\frac{q_w}{c\rho} = \left(\frac{k}{c\rho} + \varepsilon\right)\frac{d\theta}{dy} \quad . \quad . \quad . \quad (3)$$

and with

$$u^+ = -3{\cdot}05 + 5\log_e y^+$$

$$\varepsilon = \frac{\mu}{\rho}\,\frac{y^+}{5} - \frac{\mu}{\rho}.$$

On substitution in equation (3) and integration between $y^+ = 5$ and $y^+ = 30$ the buffer-layer temperature drop

$$(\theta_1 - \theta_2) = \frac{5q_w}{c\rho}\sqrt{\left(\frac{\rho}{\tau_w}\right)}\log_e(5\mathrm{Pr} + 1). \quad (4)$$

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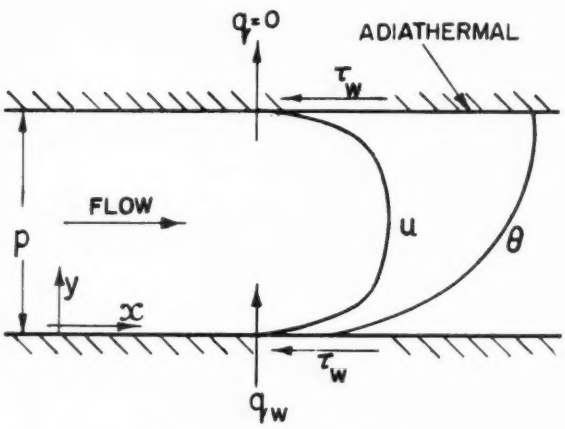

FIGURE 1. Asymmetric heating.

In the case of asymmetrical heating, the Reynolds analogy cannot be applied directly in the turbulent region, because the velocity and temperature profiles are dissimilar as shown in Fig. 1. The wall distance where the local temperature equals the bulk temperature of the fluid is different to the wall distance where the local velocity equals the average velocity. This applies even when the value of the Prandtl number is unity. A solution to this difficulty has been outlined by Mizushina[1]. His method can be used in the present problem as follows.

Symmetrical heating of the fluid is first considered when the Reynolds analogy is applied in the turbulent region and therefore

$$\frac{\theta_{2s}-\theta_{bs}}{q_{ws}}=\frac{\bar{u}-u_2}{c\tau_w}. \qquad (5)$$

the specific heat flux and shear stress being assumed equal to the wall values, as previously. Mizushina assumed that:

1. The velocity is uniform in the turbulent region
2. The eddy diffusivity of heat ε is constant across the turbulent region

and 3. The axial temperature change $\Delta\theta$ is equal across the fluid section.

Then, for flow between parallel plates

$$\rho c\varepsilon\frac{d\theta}{dy}x=\bar{u}\rho c\Delta\theta\left(\frac{p}{2}-y\right)$$

and

$$q_w x=\bar{u}\rho c\Delta\theta\left(\frac{p}{2}-y_2\right),$$

considering unit width of plate.

Eliminating $\Delta\theta$, separating the variables and integrating, the temperature is given by

$$\theta_s=\theta_{2s}-\frac{q_w}{\rho c\varepsilon\left(\frac{p}{2}-y_2\right)}\left\{\frac{py}{2}-\frac{y^2}{2}-\frac{py_2}{2}+\frac{y_2^2}{2}\right\}.$$

With constant fluid properties, a reasonable assumption for gases, the bulk temperature θ_{bs}

$$\theta_{bs}=\left(\frac{1}{\frac{p}{2}-y_2}\right)\int_{y_2}^{p/2}\theta dy.$$

Substituting for θ, and integrating,

$$\frac{\theta_{2s}-\theta_{bs}}{q_{ws}}=\frac{2}{\rho c\varepsilon(p-2y_2)^2}\left[\frac{p^3}{12}-\frac{p^2y_2}{2}+py_2^2-\frac{2}{3}y_2^3\right]. \qquad (6)$$

For the asymmetrical case, the thermal resistance of the turbulent core is obtained by the same method

$$\frac{\theta_2-\theta_b}{q_w}=\frac{1}{\rho c\varepsilon(p-y_2)^2}\left[\frac{p^3}{3}-p^2y_2+py_2^2-\frac{y_2^3}{3}\right]. \qquad (7a)$$

Combining equations (5), (6) and (7*a*), the turbulent core temperature drop for asymmetrical heating is

$$\theta_2-\theta_b=q_w\frac{1/(p-y_2)^2}{2/(p-2y_2)^2}\frac{(p^3/3-p^2y_2+py_2^2-y_2^3/3)}{(p^3/12-p^2y_2/2+py_2^2-2y_2^3/3)}\frac{\bar{u}-u_2}{c\tau_w}$$

Since y_2 (the laminar sub-layer and buffer-layer thickness) is small compared with the plate spacing p then

$$\theta_2-\theta_b=2q_w\left\{\frac{\bar{u}-u_2}{c\tau_w}\right\}, \text{ approximately}$$

$$=\frac{2q_w}{\rho c}\sqrt{\left(\frac{\rho}{\tau_w}\right)}\left\{\frac{\bar{u}}{\sqrt{(\tau_w/\rho)}}-u_2^+\right\}.$$

Now $u_2^+=5(1+\log_e 6)$ at $y^+=30$

when

$$(\theta_2-\theta_b)=\frac{2q_w}{\rho c}\sqrt{\left(\frac{\rho}{\tau_w}\right)}\left\{\frac{\bar{u}}{\sqrt{(\tau_w/\rho)}}-5(1+\log_e 6)\right\}. \qquad (7b)$$

Therefore adding the individual temperature drops given by equations (1), (4) and (7*b*), the total temperature drop $(\theta_w-\theta_b)$ is given by

$$(\theta_w-\theta_b)=\frac{q_w}{c\rho}\sqrt{\left(\frac{\rho}{\tau_w}\right)}\left[5\text{Pr}+5\log_e(5\text{Pr}+1)+\frac{2\bar{u}}{\sqrt{(\tau_w/\rho)}}-10(1+\log_e 6)\right]$$

$$=\frac{q_w}{c\rho}\sqrt{\left(\frac{\rho}{\tau_w}\right)}\left[\frac{2\bar{u}}{\sqrt{(\tau_w/\rho)}}+5(\text{Pr}-2)+5\log_e\left[\frac{5\text{Pr}+1}{36}\right]\right].$$

With

$$\sqrt{\left(\frac{\tau_w}{\rho}\right)}=\frac{\bar{u}\sqrt{0{\cdot}0395}}{\text{Re}^{1/8}},$$

the heat transfer coefficient equation

$$\text{Nu}=\frac{\text{RePr}q_w}{c\rho\bar{u}(\theta_w-\theta_b)}$$

then becomes

$$\text{Nu}=\frac{0{\cdot}1986\,\text{Re}^{\frac{7}{8}}\text{Pr}}{\left[10{\cdot}06\text{Re}^{\frac{1}{2}}+5(\text{Pr}-2)+5\log_e\left(\frac{5\text{Pr}+1}{36}\right)\right]}. \qquad (8)$$

For symmetrical heating,

$$\text{Nu}=\frac{0{\cdot}1986\text{Re}^{\frac{7}{8}}\text{Pr}}{\left[5{\cdot}03\text{Re}^{\frac{1}{2}}+5(\text{Pr}-1)+5\log_e\left(\frac{5\text{Pr}+1}{6}\right)\right]}. \qquad (9)$$

and these equations ((8) and (9)) are compared in Figs. 2 and 3 with the recognised dimensional analysis type equation

$$\text{Nu}=0{\cdot}023\text{Re}^{0{\cdot}8}\text{Pr}^{0{\cdot}4} \qquad (10)$$

which satisfactorily correlates the experimental data for air and water with symmetrical heating. Equations (9) and (10) show good agreement for Pr = 0·7 while equation (10) for asymmetrical heating predicts lower values of the Nusselt number. Fig. 3 indicates that the ratio of Nusselt number for asymmetrical heating to that for symmetrical

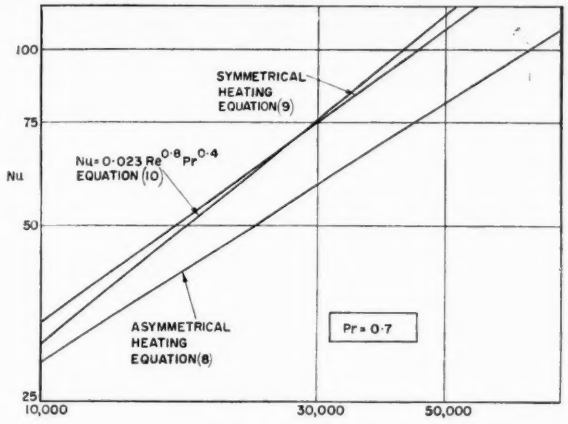

FIGURE 2. Variation of heat transfer coefficient Nu with Reynolds Number, Re.

heating is about 0·75 for gases and about 0·88 for water. The difference in equations (8) and (9) becomes more pronounced as the Prandtl number decreases. For very low values of the Prandtl number, as in the case of molten metals, the above analysis does not apply as heat transfer by thermal conduction in the turbulent region was neglected. The problem of asymmetrical heating of these fluids has been investigated by Harrison and Menke[2].

CONCLUSIONS

An equation has been derived for the heat transfer coefficient in asymmetrical heating of a fluid in turbulent flow between parallel plates, based on

1. The universal velocity profile for the velocity distribution.
2. The hydraulic radius concept for friction.

and 3. An extension of the analogy between heat transfer and fluid friction by Mizushina[1].

The heat transfer coefficient equation predicts lower values than those for symmetrical heating, the difference increasing with decreasing Prandtl number. The range of Prandtl number, for which the equation is valid, is limited in view of the assumptions made. Since fluid properties have been assumed constant the result is probably most accurate for gases.

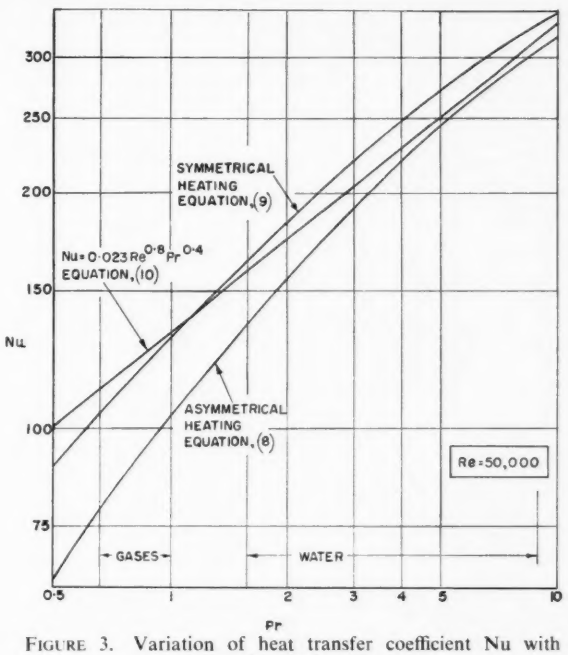

FIGURE 3. Variation of heat transfer coefficient Nu with Prandtl number, Pr.

REFERENCES

1. MIZUSHINA, T. (1951). General Discussion on Heat Transfer. Analogy between Fluid Friction and Heat Transfer in Annuli. *Inst. Mech. Eng.*, p. 191, 1951.
2. HARRISON, W. B. and MENKE, J. R. (1949). Heat Transfer to Liquid Metals Flowing in Asymmetrically Heated Channels. *Trans. A.S.M.E.*, Vol. 71, p. 797, 1949.

The Production of Duct Velocity Profiles Having High Ratios of Maximum to Mean Velocity

by

J. L. LIVESEY, B.Sc., D.I.C., E. PARKER, M.Sc., and P. K. JONES, B.Sc.
(University of Manchester)

THE RESULTS are presented of an investigation of a particular type of baffle for the production of symmetrical velocity profiles having high ratios of maximum to mean velocity in ducted incompressible flow. Two similar families of profiles are obtained depending on whether a short (12 diameters) or a long (48 diameters) entry length is used before the baffle. The highest value of the maximum to mean velocity ratio obtained is 1·42 and the pressure loss coefficients associated with the use of the baffle are given together with an indication of the effect of Reynolds number.

INTRODUCTION

This investigation formed a small part of an investigation into the performance of the inlet sections of gas turbine combustion chambers in which one variable was the entry velocity profile. In the gas turbine, ratios of maximum to mean velocity of the order of 1·4 may exist in the entry to the combustion chamber, depending on the type of compressor used and its proximity to the combustion chamber. A baffle produced in this connection has been examined in some detail .

There are many problems in internal flows which are critically dependent on the entry velocity profile to the system, and it was thought that a simple method for varying the velocity profile in a duct might be of interest to other workers in similar fields.

APPARATUS AND TESTS

The baffle, which is shown in Fig. 1, consisted of a plate placed in the duct in a plane perpendicular to the duct axis. The plate was pierced by a large central hole,

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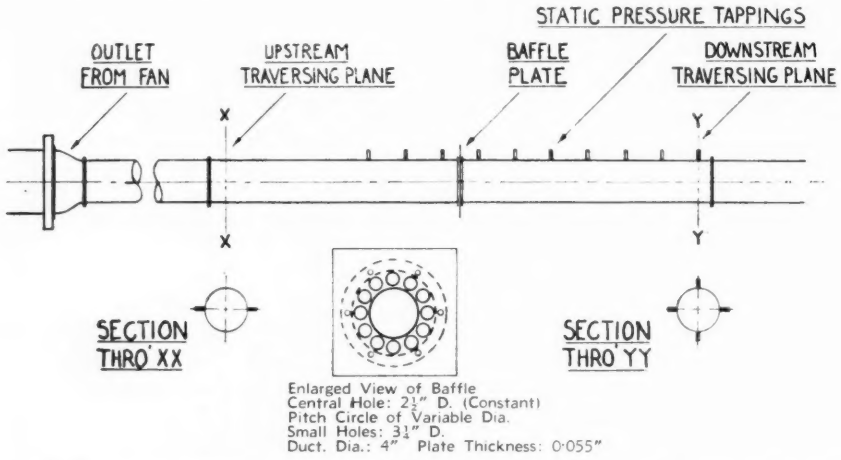


FIGURE 1.

in the manner of an orifice plate, and in addition twelve equal smaller holes pierced the plate in a symmetrical array; the pitch circle of the smaller holes being situated in the centre of the annular ring formed by the large central hole and the duct wall.

The 4-in. diameter duct carrying the baffle was supplied with air from a centrifugal compressor through a contraction (area ratio 2·25). The length of the entry pipe before the baffle was varied by bolting together 2 ft. lengths of the 4-in. pipe. Static pressure tappings and Pitot traverse guides were situated as shown in Fig. 1. The entry and exit traverse stations were situated 22·5 in. from the plane of the baffle. The entry velocity profile was determined across one diameter and the exit velocity profile across two diameters at right angles. The choice of the position of the exit traverse station was governed by the length of duct needed for the re-expansion of the flow after the contraction at the baffle. Fig. 2 shows a typical static pressure distribution along the duct and it can be seen that the pressure recovery, from the high suction created by the contraction of the stream at the baffle, was completed in 20 in. of duct and after this the pressure drop due to pipe friction began to appear.

The test consisted principally of a determination of the effect of increasing the diameter (d), of the twelve equal small holes in the baffle, on the exit velocity profile and on the total pressure loss (ΔP) due to the baffle. Two series of tests were carried out, one with an entry length before the baffle of 12 duct diameters and one with an entry length of 48 diameters; these gave entry velocity profiles with ratios of maximum to mean velocity V_{max}/V_{mean} of 1·05 and 1·15 respectively. A subsidiary test was also carried out using a fixed baffle configuration and varying the mean velocity in the duct, to assess the effect of varying the Reynolds number by changing the velocity level.

RESULTS

V_{max}/V_{mean} Variation

Figure 3(*a*) shows the variation of V_{max}/V_{mean} for the exit profile with d/D for both short (12 diameters) and long (48 diameters) entry lengths. In the initial stages as d/D rises, the rate of increase of V_{max}/V_{mean} with d/D is small then, in the intermediate range of d/D the rate of increase rises rapidly and finally when the small holes approach the point at which they break through into the central hole, the rate of increase falls rapidly. In one case a baffle was tested with a small hole size just large enough to break through into the central hole and this resulted in a rapid fall in V_{max}/V_{mean} confirming the approach to a maximum indicated by the curves shown in Fig. 3(*a*). With the long entry length (entry V_{max}/V_{mean} of 1·15) higher values of exit profile V_{max}/V_{mean} are obtained than with the short entry length (entry V_{max}/V_{mean} of 1·05). It should be noticed that for small values of d/D the baffle has the effect of reducing the value of V_{max}/V_{mean} from entry to exit, *i.e.* the profile is rendered more uniform.

Total Pressure Loss

Figure 3 (*b*) shows the variation of the total pressure loss coefficient due to the baffle with d/D. It is evident that the baffle is an extremely high loss device for low values of d/D but for high values of d/D, producing the highest values of V_{max}/V_{mean} at exit, which is the condition for which the baffle was developed, the loss is reasonable amounting to one or two dynamic heads.

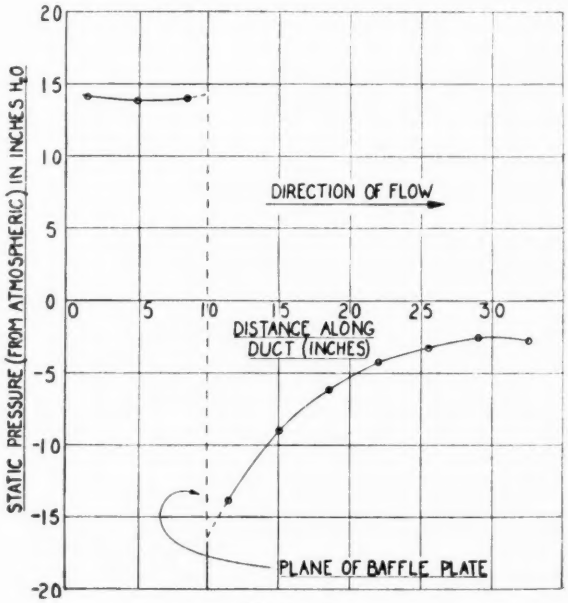


FIGURE 2.

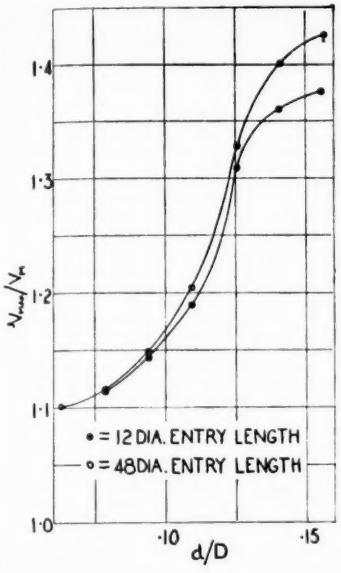


FIGURE 3(*a*).

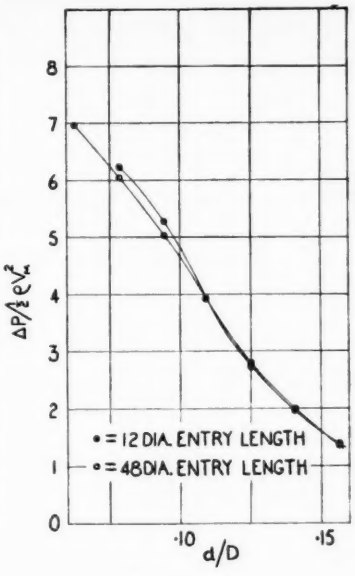
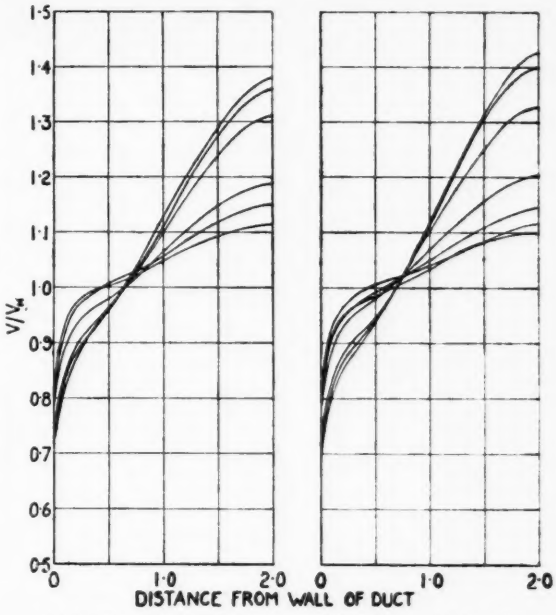


FIGURE 3(*b*).



(*a*) 12 dia. entry length (*b*) 48 dia. entry length

FIGURE 4. Exit velocity profiles.

Velocity Profiles

Figures 4(*a*) and 4(*b*) show the two families of outlet profiles obtained with the short and long entry lengths respectively. The profiles correspond to the points on Figs. 3(*a*) and 3(*b*) and can be identified individually by the axial value of velocity ratio in Figs. 4(*a*) and 4(*b*) which gives the value of V_{max}/V_{mean}. It may also be noticed that all the profiles intersect in a fairly closely defined region at a radius equal to 0·625 of the duct radius; the value of V_{max}/V_{mean} in this region is 1·02. A quick estimate of the mean velocity in the duct may, therefore, be made by a spot measurement of velocity at this radius divided by 1·02.

Reynolds Number Effect

An attempt was made to assess the effect of a change of Reynolds number due to a change of velocity level by testing one baffle ($d/D=0{\cdot}156$) over a wide range of velocities using the 48 diameter entry length.

With a mean velocity change from 70 to 170 ft./sec. representing a Reynolds number based on duct diameter, from 1·53 to $3{\cdot}59\times10^5$, the value of V_{max}/V_{mean} for the exit profile changed from 1·416 to 1·420, *i.e.* a change hardly measurable to the accuracy of these tests. At the same time there was a small but definite increase in total pressure loss coefficient from 1·32 to 1·39.

It appeared, therefore, that a factor of 2·3 in Reynolds number produced little significant change in the performance of the baffle. Accordingly the mean velocity level during the tests was allowed to vary by an amount less than this (a factor of 1·55) as was convenient during the tests. The mean velocity levels used during the tests were as follows:

Short entry length	111-122 ft./sec.
Long entry length	106-172 ft./sec.

The generally lower velocity level in the short entry length tests was necessary to maintain symmetry in the entry velocity profile.

Effect of Symmetry

A characteristic which became apparent on comparison of the two sets of tests, with different entry profiles, was the effect of asymmetry in the entry flow and its propagation through the baffle. When used in conjunction with a fairly uniform (or "square") entry profile with V_{max}/V_{mean} of, say, 1·05 any initial asymmetry of the profile was exaggerated in passage through the baffle. On the other hand with a less square (or "Peaky") entry profile with V_{max}/V_{mean} of, say, 1·15, any initial asymmetry was diminished in passage through the baffle. It would appear necessary, therefore, when using this baffle with a short entry length, to ensure that the entry profile is symmetrical.

CONCLUSIONS

A baffle has been produced which enables the parameter V_{max}/V_{mean} to be varied from 1·1 to 1·42. The pressure losses incurred by the baffle are high for low values of V_{max}/V_{mean} but are reasonable for the high values where the baffle is most likely to be used. The effect of Reynolds number due to change of mean velocity level is small over the range 70 to 170 ft./sec. A rapid method of estimating the mean velocity is available from one spot reading of local velocity in the duct for the whole family of profiles. The asymmetry of the entry flow is exaggerated for "square" entry profiles and is diminished for "peaky" entry profiles.

It is considered that much higher values of V_{max}/V_{mean} could be produced by either

(*i*) using baffles in series,

(*ii*) reducing the diameter of the central hole slightly to enable an extension of the range of d/D to be obtained without breaking through into the central hole.

Both methods would incur penalties in pressure loss.

Leakage Rates from Pressurised Aircraft at Altitude

by

D. P. HUGHES

IN A TECHNICAL NOTE by H. J. Staite published in the August 1954 issue of the JOURNAL (p. 574) expressions for the leakage rates from pressurised aircraft at altitude were developed.

I wish to point out an error in the analysis for the case when the pressure ratio is above the critical, *i.e.* when in the notation previously used

$$p/p_0 \geqslant \left(\frac{n+1}{2}\right)^{n/(n-1)}.$$

The velocity through the hole is now the local speed of sound

$$v = \left(gn\frac{p_t}{\rho_t}\right)^{\frac{1}{2}}. \quad . \quad . \quad . \quad . \quad (1)$$

where p_t is the static pressure in the leakage hole, *not* the atmospheric pressure.

p_t is now independent of the atmospheric pressure and is given by

$$p/p_t = \left(\frac{n+1}{2}\right)^{n/(n-1)}$$

i.e.
$$p_t = p\left(\frac{2}{n+1}\right)^{n/(n-1)}. \quad . \quad . \quad . \quad (2)$$

and
$$\rho_t = \left(\frac{p_t}{p}\right)^{1/n}\rho$$

i.e.
$$\rho_t = \left(\frac{2}{n+1}\right)^{1/(n-1)}\rho. \quad . \quad . \quad (3)$$

Combining equations (1), (2) and (3) with equation (8) of the previous Note, the mass leakage rate can be written

$$\frac{-dm}{dt} = a\left[gn\left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}p\rho\right]^{\frac{1}{2}}. \quad . \quad (4)$$

Equating expression (4) with equation (3) of the previous Note, gives

$$\frac{-dp}{dt} = \frac{a}{V}n\left[gn\left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}\right]^{\frac{1}{2}}\frac{p^{5/2}}{\rho^{\frac{1}{2}}}. \quad (5)$$

Therefore, dividing equation (10) of the previous Note, by equation (5), with the appropriate subscripts, 1 and 2 respectively, the time factor f is given by:—

$$f = \left(\frac{p_{01}}{p_1}\right)^{1/n}\left(\frac{p_1}{p_2}\right)\left[1-\left(\frac{p_{01}}{p_1}\right)^{\frac{n-1}{n}}\right]^{\frac{1}{2}}\sqrt{\left\{\frac{2}{n-1}\left(\frac{n+1}{2}\right)^{\frac{n+1}{n-1}}\right\}}$$
$$. \quad . \quad . \quad (6)$$

It should be noted that equation (10) of the previous Note has been incorrectly printed and should read

$$-\frac{V\rho}{np}\cdot\frac{dp}{dt} = \rho\left(\frac{p_0}{p}\right)^{1/n}a\left[2g\left(\frac{n}{n-1}\right)\frac{p}{\rho}\left\{1-\left(\frac{p_0}{p}\right)^{\frac{n-1}{n}}\right\}\right]^{\frac{1}{2}}$$

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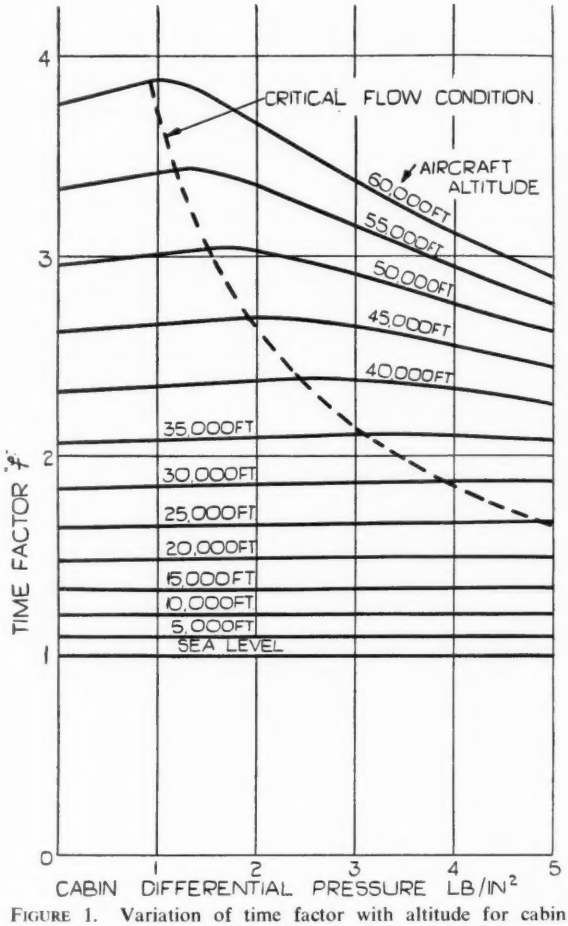

FIGURE 1. Variation of time factor with altitude for cabin leakage.

MR. STAITE'S REPLY

I am grateful to Mr. Hughes for pointing out the error in the analysis when the pressure ratio is above the critical. I am in full agreement with Mr. Hughes's derivation of the time factor f for this condition. Fig. 1 is a revised graph showing constant altitude lines which have no discontinuity in slope through the critical condition, which is in agreement with the mathematics.

I also agree with Mr. Hughes that equation (10) of my Note has been incorrectly printed and should read as he states.

It is of interest that in May-June 1955, leakage tests up to an altitude of 40,000 ft. were made by the Ministry of Supply at the Aeroplane and Armament Experimental Establishment at Boscombe Down using a medium bomber. These tests were concerned mainly with below critical flow conditions and showed very good agreement with the theory. Further tests are planned to cover the case of above critical flow conditions and the revised graph (Fig. 1) for this part of the range should be of use to compare with the experimental results.

Graduates' and Students' Section

This page of the Journal is written by members of the Committee of the Graduates' and Students' Section. Each month it covers matters of interest and importance to Graduates and Students and previews lectures and visits.

THE SUMMER PARTY for students, graduates and their friends will be held at 4 Hamilton Place on Friday 22nd June. We hope you will come along—it will be a completely informal affair, with an ample supply of free wine, beer, soft drinks and refreshments. Dancing and games are planned and, it is hoped, one or two novelty events whose details will be revealed only on the evening itself. The party will be from 8 to 11.30 p.m.; tickets are 5s. each.

This party is, frankly, an experimental one. If it is a success—and that depends on your support—we hope it will set the pattern for others in future. For a long time the Committee have felt that members would appreciate a party of this kind.

This one has been arranged to ensure that even the poorest student can afford to come and have a good evening out with his friends. To keep expense to the lowest possible level the members of the Commitee will act as barmen, disc-jockeys, sandwich-makers, etc. In this way we hope to ensure that everyone will be able to enjoy a party at which there is a good supply of drink and food (including ham sandwiches) for the ridiculously low all-in charge of 5s.

If you have not already done so, please will you apply for your tickets to:—

J. R. Cownie,
4 Lyndale Avenue,
Cricklewood,
London, N.W.2.

Please apply soon; we may have to limit numbers if we receive too many applications.

VISITS

One letter received in reply to the Chairman's appeal with the February JOURNAL for suggestions came from Mr. D. J. Evans of Rolls-Royce at Derby. It was gratifying to receive a suggestion from a member in the provinces on how the Section could overcome the shortcomings of its centralisation in London. Mr. Evans deplored the fact that his participation in the Section's affairs was limited to a glance at the programmes of lectures and visits.

He suggested tentatively that for a slight increase in subscription and membership fees, members away from London could receive a report on the Section's proceedings as a supplement to the JOURNAL.

The secretary would be glad to hear other members' views on this point. It was the original intention with this page to give a summary where possible of coming or recent events. This has not been accomplished too well so far, but it is intended to delegate responsibility to one person on the new Committee when it takes office in July so that it is hoped to fulfil this aim later.

The most recent visit at the time of writing was that made in early April to the Royal Air Force Station at West Malling, near Maidstone. As some may recall, a visit was planned for last September, but it had to be cancelled owing to the station's busy commitments in connection with a big air exercise. The Section was quite honoured in being granted a visit since application had to be made to the Secretary of State for Air, a dignitary who had to be absolved from responsibility for the visitors' safety as they boarded an R.A.F. 'bus at West Malling Station.

Disappointingly, few people came; whether this was due to the weather, which was rather cold, or the aftermath of Easter was not certain, but those who went felt that it was worth while, and that they saw much of interest.

West Malling is a fully operational station of Fighter Command, equipped with all-weather Meteors N.F. Mks. 12 and 14. It is also the base of No. 500 (County of Kent) Squadron, Royal Auxiliary Air Force, operating Meteors Mk. 8 day fighters. We did not call in on the "Auxiliaries" because they were busy at their week-end's flying—this could be seen and heard much of the time!

We were shown the servicing shops for the A.I. (Airborne Interception) and other radar equipment. This means little to an "airframe man" like the writer, but it was most impressive to see an A.I. unit on the bench with its scanner scanning. Quite a large mass comprising the scanner bowl and associated aerials was moved to and fro at several cycles per second. The vibration in the hut was considerable; the vibration in the nose of an aircraft can be imagined!

Next the G.C.A. unit was visited, a large striped trailer with big diesel generators to power it, and the working space crammed to the roof on all sides with "black boxes" and instruments. One could comprehend the function of the main screen upon which one could follow the progress of aircraft flying over a large area of Kent and notice the effect of hills and other "false echoes" which help to confuse in the use of such equipment. No actual talk-downs were done while we were there, but the procedure was explained.

At the Control Tower, the party was shown the procedure of bringing in aircraft from the coast by radio in overcast conditions. This is very important with jet fighters having limited endurance. For our benefit, a meteor on a practice flight was directed from somewhere over the South Coast at 35,000 ft. down to about 1,000 ft. over the aerodrome through eight-eighths cloud. In a hangar, we inspected a Meteor N.F.14 and a Venom night fighter.

Among details noticed were the names Townsend and Cunningham among the lists of decorations and station commanders. Also noted were the instructions in the briefing room in connection with a flight by the "Tenth Commonwealth and Empire Lecturer."

The visit concluded with a pleasant tea served in the spacious mess dining hall, which must be one of the finest in the country.—N.K.B.

THE LIBRARY
Reviews

GUIDANCE. *Arthur S. Locke and others. Van Nostrand, New York, Macmillan, London 1955. 729 pp. Illustrated. 90s.*

This is the first in a new American series of five volumes on "Principles of Guided Missile Design" edited by Capt. Grayson Merrill, U.S.N., who has been connected with U.S. Naval missile development since its earliest days. The avowed purpose of the Series is to set forth the underlying principles and technological background of guided weapon design for the benefit of graduate students, professional engineers and technical officers of the armed services. Because of the wide range of technical subjects involved in missile guidance, this book has been prepared by a team of specialists all of whom are experienced professionals in their field, and many of whom are well known to British workers.

The present volume is the first comprehensive technical treatment of the key subject of missile guidance to appear in the United Kingdom and probably also in the United States; as such it should be of particular interest to the growing number of scientists and engineers engaged in the British missile development field, not only for the subject matter but also because the information presented is in startling contrast to the meagre details so far released by the security authorities in this country.

The presentation starts with a rather simplified discussion of the main classes of missiles, with reference to wartime examples, and proceeds through an obviously naval-inspired description of the elements of inertial navigation, including various chart projections, to a useful review of the factors which affect the transmission of radio waves, including the effects of rocket flame attenuation, followed by a chapter on the emission, transmission and detection of infra-red radiation. In preparation for later chapters there follows next a quite well chosen treatment of the more important mathematical methods required for the study of linear networks and servo systems. It is however not true, as claimed at the beginning of this section, that the reader can proceed thereafter on the basis of "elementary algebra and calculus"; rather the following chapters are a useful revision course for those who already have a good knowledge of network and servo theory, and wish to apply it to missile guidance problems. There is a tendency to give the obvious "textbook" methods with the inference that they are of great practical utility, as for example the Laplace transform. In a section on feedback stability there is an error in the drawing of a Nyquist diagram (Fig. 6-13) and the stable system illustrated in the next diagram is erroneously said to be derived from the first by reducing the gain.

The later parts of the book deal with the measurement of missile motion by the control system, and with methods of detection and guidance, before going on to a theoretical and descriptive treatment of all the usual systems of guidance for air-to-air and surface-to-air missiles. This, together with a mathematical analysis of the types of flight paths, is the most extensive treatment of guidance systems yet published and gives a lucid account of the technical pros and cons of various possible guidance solutions for the more important weapon applications. The final chapters on simulation and telemetry contain little new information.

The general impression left by this book is that the contents tend to reflect the enthusiasm and specialisation of the individual contributors, without entirely fitting into a balanced treatment of the whole subject. Nevertheless it has a special value in gathering together all the specialist subjects which are involved in the complex field of missile guidance. It is well printed and profusely illustrated by useful and clearly presented diagrams; there is an extensive index and appropriate bibliographies are given at the end of each chapter. Inevitably the book, although it runs to 729 pages, is neither a complete treatise on the subject nor a summary introduction; it should however be of great interest and educational value to technically qualified newcomers in the guided missile field and to many of those already engaged in this new and exciting activity.—W. H. STEPHENS.

PROCEEDINGS OF THE CONFERENCE ON HIGH-SPEED AERONAUTICS, POLYTECHNIC INSTITUTE OF BROOKLYN, 1955. *Edited by A. Ferri, N. J. Hoff and P. A. Libby. Published by Polytechnic Institute of Brooklyn, 1955. 392 pp. Illustrated. $5.25.*

The sixteen papers included in these Proceedings cover a wide range of subjects in the field of aerodynamics and structures. It is a pleasure to see that the first paper is a review by Th. von Kármán of "solved and unsolved problems" in high-speed aerodynamics. In this connection "solved" applies to topics "whose further development appears to be assured, provided sufficient industry and skill are applied to them." The second paper is an excellent review by H. L. Dryden of work on boundary-layer transition, covering both low and high speeds and including an extensive bibliography.

In a stimulating paper, A. Busemann considers the noise heard on the ground due to an aircraft in supersonic flight. Pointing out that conventional measures to reduce drag will have little effect on the noise, the author refers briefly to the Busemann biplane of 1935 and hints that unconventional methods may be effective some day in reducing the noise. In a paper on "Test Facilities for Ultra-High Speed Aerodynamics," R. Smelt discusses the limitations of hypersonic wind tunnels and considers methods of experiment for Mach numbers greater than 12, *i.e.* above the useful range of a hypersonic tunnel. A paper on a similar subject by A. Kantrowitz is unfortunately presented only as an abstract.

There are four papers dealing with structural problems of supersonic flight. J. E. Duberg gives a brief review of recent N.A.C.A. work in this field. A review of the subject is also given by W. H. Horton of the R.A.E., with emphasis on some of the experimental methods that have been used at the R.A.E. for studying thermal stresses. There is a useful paper by N. J. Hoff on "Stress Distribution in the Presence of Steady Creep," and another paper by L. Broglio of the University of Rome on the "Balance Method" in thermal stress analysis.

The remaining papers are concerned with various topics in aerodynamics, including a theory of shock-wave boundary-layer interaction, transonic flow, flow through cascades, and blow-down supersonic and hypersonic wind tunnels.

The Proceedings contain much useful material that is not available in any other form.—W. A. MAIR.

AERO-ELASTICITY. *Raymond L. Bisplinghoff, Holt Ashley and Robert L. Halfman. Addison Wesley Publishing Co. Inc., Cambridge, Mass., 1955. 860 pp. Illustrated. $14.50.*

Although aero-elasticity, as an aeronautical problem, is by no means new, it has become a problem of major practical importance only comparatively recently, within perhaps the past ten years. This is one reason why very few textbooks yet deal with it, another reason being the scope and complexity of the problem. The reviewer knows of only three earlier publications concerned with the subject, one American and two British: "An Introduction to Aircraft Flutter and Vibration" by Scanlan and Rosenbaum (1951), "The Elementary Theory of Aero-Elasticity" by Broadbent, an *Aircraft Engineering* Monograph (1954), and "Massbalancing of Aircraft Control Surfaces" by the reviewer, a Royal Aeronautical Society Monograph (1954), which dealt only with control surface flutter. There is also a very recent American publication in the GALCIT Aeronautical Series, "An Introduction to the Theory of Aero-Elasticity" by Y. C. Fung (1955), but this is known to the reviewer only by name.

It is evident, however, that the present book is the most ambitious so far in that it purports to deal with the whole field of aero-elasticity, embracing both theoretical and experimental treatments, and it does not pretend to be elementary. The authors, in fact, acknowledge no omissions. A paramount feature of aero-elasticity is that it embraces structural and aerodynamic problems of almost equal magnitude, and this makes for same difficulty in the writing of a comprehensive treatise on the subject, since the present generation of aero-elasticians tend individually to be more expert in the one or the other of these two major aspects. In this book the difficulty has been met by the joint authorship, Bisplinghoff concentrating on the structural aspects and Ashley on the aerodynamic. The part of the book concerned with experimental methods is from Halfman.

A notable feature of the book, in fact, is that roughly half of its 800 odd pages is devoted to what the authors call the tools of the aero-elasticity, namely the mathmatical theory of the structural and aerodynamic aspects. Apart from an introductory chapter the remaining twelve chapters fall into four groups of three. The first group presents the structural tools and the second the aerodynamic tools. The third group demonstrates their application to the three broad aero-elastic phenomena: static aero-elasticity, flutter, and dynamic response phenomena. The final group describes the experimental techniques that are used, both model and full scale, for studying or predicting aeroelastic phenomena. It is impossible in a review of this kind to describe the subject matter of the book in any detail; only a broad indication of the contents can be given, with a few salient comments.

The three chapters of the first group, dealing with the structural tools, cover deformations of aeroplane structures under static loads, deformations under dynamic loads, and the calculation of natural mode shapes and frequencies. Basic analytical approaches via the differential equation, the integral equation, and energy methods are presented, with numerous examples. Influence coefficients and influence functions associated with the integral equation approach are described and their calculation discussed. Matrix forms of analysis suitable for high speed digital computors are given prominence.

The three chapters of the second group, dealing with the aerodynamic tools, cover two- and three-dimensional incompressible flow, compressible flow, and wings and bodies in three-dimensional unsteady flow. The first of these deals with aerofoils and wings in steady flow (by vortex sheet theory), with oscillating aerofoils (by Theodorsen's method), and with arbitrary motion of aerofoils (by Fourier—integral superposition). The second deals to some extent with wings and aerofoils in steady subsonic and supersonic flow, but mainly with aerofoils oscillating and in arbitrary motion. For oscillating aerofoils Possio's theory is presented for subsonic flow and Garrick's method of source pulses for supersonic flow. Indicial admittance functions, derived by Fourier superposition, are applied to the problem of arbitrary motion. The third chapter of this group deals with oscillating wings in incompressible flow (by Reissner's methods), in subsonic flow (by Watkins' kernel function method), and in supersonic flow (by superposition of elementary source or doublet solutions). Consideration is also given to the influence of sweep, both the streamwise and normal component approaches being presented. Very low aspect ratio wings and non-lifting bodies are also considered, and mention is made of the reverse flow theorem and its potential applications. The reviewer found the general layout of these three chapters rather confusing in respect of the order in which two- and three-dimensional cases, steady and unsteady cases, and incompressible and compressible flows were considered.

The various aero-elastic phenomena, and the use of the foregoing tools in the theoretical study of these phenomena, are described in the next group of three chapters. The first deals with the simpler static phenomena; general conditions of symmetric and antisymmetric wing lift distributions are considered, leading to the more specific phenomena of divergence and aileron effectiveness. Unswept and swept wings are treated separately, and some mention is made of the aero-elastic behaviour of chordwise strips in relation to low aspect ratio wings. Analytical techniques based on the differential equation, the integral equation, and on energy methods are described; the main emphasis is on approximate solutions for practical wings, but some particular closed form solutions are demonstrated. Nothing is said on the aero-elastic effects connected with fuselage and tail flexibilities.

The next chapter, on flutter, begins with a discussion of the nature of flutter, exemplified by a simple aerofoil pitching about its leading edge. The general characteristics of wing flexure-torsion flutter are then represented by those of a binary aerofoil system. There follows an interesting "exact" treatment for the flexure-torsion flutter of a uniform cantilever wing, as an introduction to the main consideration of flutter prediction for practical wings by approximate methods. This is prefaced by a useful illustration of the manner in which the aero-elastic modes (the natural modes in flight) progressively change with air speed towards a critical flutter condition. The practical prediction of flutter, based on the assumption of semi-rigidity and a combination of assumed modes, is illustrated by three numerical examples. Some consideration is given to the question of whether normal or artificial modes are best suited for the purpose. Then follows an example of the inclusion of aerodynamic finite span effects using Reissner's theory, some consideration of the effect of compressibility, a comparison of the streamwise and normal section approaches in the flutter analysis of swept wings, and an example of the type of flutter analysis possible for a low aspect ratio wing. In connection with the latter aspect, mention is made of the possible application of the reverse flow theorem as a method of

incorporating more accurate aerodynamic theories in flutter analyses. This chapter concludes with an outline of some types of single degree of freedom flutter and a mention of stall flutter, panel flutter, and bridge flutter.

The final chapter of this group deals with dynamic response phenomena in respect of the overall response of the elastic aeroplane and of the stresses produced in the structure. General equations of motion based on influence functions are treated on the assumption of a finite number of degrees of freedom in terms of the normal modes. Systems with prescribed time—dependent external forces (*e.g.* the landing problem) are analysed on the basis of indicial admittances and Duhamel's integral. For systems with motion—dependent external forces (*e.g.* the gust problem)—solutions are demonstrated using Laplace transforms, frequency response methods, or finite differences. Finally, a description is given of the use of power spectrum analysis in treating the problem of dynamic response to random turbulence.

The last group of chapters covers the experimental approach to aero-elastic investigations. The first of these is devoted to aero-elastic model theory and is primarily concerned with establishing and illustrating the principle of deriving the appropriate scale relationships from the non-dimensional equations governing the phenomenon. The second chapter deals with model design and construction and considers separately the simulation of the elastic and the inertial properties and of the external aerodynamic shape. It includes an interesting discussion of the difficulty of designing a beam network model to a prescribed set of influence coefficients. The final chapter describes the various testing techniques, both model and full scale. These cover the measurement of structural flexibilities, the measurement of natural frequencies and mode shapes, wind tunnel and rocket model tests, and flight flutter tests. In connection with the last named there is, to the reviewer's mind, an irrational and undesirable emphasis on the danger associated with them. If the danger aspect of flight flutter tests is to be mentioned, it should be made clear that essentially the danger lies in designing aeroplanes to such low theoretical margins of flutter safety that flight flutter tests become necessary, and that in such cases flight flutter tests are in fact the safest method of checking the margins.

The book ends with three short mathematical Appendices (on matrices, integration by weighting numbers, and linear systems), with a long list of references grouped against the various chapters, and with an Author and a Subject Index.

By the time the end of the book is reached the overall impression is undoubtedly that here is an outstanding contribution to the literature on aero-elasticity. The main features contributing to this impression are the scope of the book and the detailed consideration given to the methods of theoretical analysis. In the latter respect there is a commendably up-to-date quality about the book, as evidenced for instance by the reference to possible applications of the reverse flow theorem and by the inclusion of power spectrum analysis as applied to turbulence response. Other commendable features are the readability, arising from the detailed clarity of the writing and from the general layout, which, apart from the criticism made earlier of the aerodynamic chapters, is logically satisfying; and the well-conceived numerical examples, which are constructively designed towards a fuller understanding of the subject matter.

The main criticism is really not so much a criticism as a comment on the relative weight Professor Bisplinghoff and his colleagues have given to the various aspects. They have clearly come down heavily in favour of the tools; and the result is as if, in building parlance, they had taken so much time to prepare a good set of constructional implements that they had had to skimp the building itself. There are some notable omissions: for example, aero-elastic effects on dynamic stability, the flutter aspects of powered controls, and the flutter of control tabs. The practising engineer will also look in vain for guidance on the interpretation of resonance test modes in relation to flutter. Other aspects are very inadequately treated; for example, the use of massbalancing in flutter prevention, the choice between normal and artificial modes in flutter analyses, and the technique of model testing by ground-launched rockets. The authors admit they have devoted relatively little space to experimental techniques but disclaim any implication that they are of minor importance. In this very complex field of aeronautics the experimental approach is certainly of major importance and merits more attention in a work that purports to deal with the whole field. While on this question of relative emphasis, it is worth mentioning that the section dealing with the three main aero-elastic phenomena is largely concerned with methods of theoretical prediction, and little with the factual information that has accumulated from research. For instance, methods of predicting aileron effectiveness and aileron reversal are considered at some length, but little is said about the effect of wing-aileron parameters on reversal characteristics.

These omissions and inadequacies plainly stem from the relative importance which the authors accord to the theoretical tools and theoretical prediction. It would indeed be wrong to disallow the importance of these aspects to a good understanding of the subject, and the emphasis had to be in this direction. The inescapable deduction is that aero-elasticity, to do it justice, requires not a book but a series of books, in which even the tools could be more fully presented than has been possible here. The fact remains, however, that within the limitations of a single book Professor Bisplinghoff and his colleagues have produced a most workmanlike account of a difficult subject. It will be of real assistance to practising engineers of this generation, and it should contribute to the development of the ideal aero-elastician of the future.—H. TEMPLETON.

WELTFLIEGER. *Wolfgang von Grönau. Deutsche Verlag-Austalt G.Mb.H. Stuttgart. In German.*

In the early twenties Alan Cobham was the pioneer of flights designed to survey the airways of the Empire, but it was left to von Grönau, in 1930, to start in earnest a series of North Atlantic survey flights by way of the Arctic Air Route, culminating in a complete circuit of the world in 1932. In that era, the public were more appreciative of the spectacular, such as the solo marathons of Lindbergh or Mollison, in which he who slept least flew farthest. The serious bread-and-butter flights, surveying the bases and examining without undue haste the problems of the routes, received less publicity at the time, but in the history of aviation these contributions are bound to take their proper place. And of all such contributions none will receive higher honour than that of Wolfgang von Grönau—a great Captain with a great crew.

In " Weltflieger,' Grönau tells the story of his early flying and the plans which led up to his first survey with the

Amundsen Wal Dornier flying boat in 1930. Starting from List, he flew by way of the Faeroes, Iceland, Ivigtut and Cartwright to New York in eight days. Next year he had an improved machine with more powerful engines, called the Gronland Wal, and with this Grönau ventured the much more difficult flight across the Ice Cap. In the flight log, there appeared the entry when half-way across Greenland at 10,000 ft. " Antenne schleppt im Schnee " (wireless aerial dragging in the snow). Grönau reached Chicago successfully 25 days after leaving List on Sylt. The final survey of 1932 lasted just over 3½ months, and in spite of a forced-landing in the Bay of Bengal, Grönau girdled the earth, taking the N. Atlantic and Pacific in his stride.

" Weltflieger " deals in the main with the three magnificent flights of the 1930-32 era, but it also touches on Grönau's subsequent life—his period of instruction in the new Luftwaffe, his war experience in Japan and China, up to his final internment. Today, as the last photograph shows, Grönau is agent for an American aircraft firm. Incidentally the standard of photographs and maps in this book is in keeping with the subject, and they are of considerable help to those whose knowledge of German is elementary.

It is hoped that an English version of " Weltflieger " will be produced, and if it is, the opportunity should be taken of eradicating certain inaccuracies, minor though they be, of historic fact concerning other Atlantic flights. For instance, Lindbergh is given the credit for the first North Atlantic flight, so is Sir Arthur Brown in another place, and the name of Richardson is recorded as one of those on board the successful American flying-boat crossing by way of the Azores. As reference to Flury's " Statistik der Oceanflüge " will show, the very first North Atlantic flight was made by an American Curtis flying-boat to which Richardson was not assigned, Sir Arthur Whitten Brown and Alcock made the first direct crossing, while Charles Lindbergh, who made the first flight from New York to Paris, was actually the seventy-fifth man to fly the North Atlantic. Before him there had been the American Curtis flying boat, the British Vimy bomber, two American Douglas seaplanes, one German airship and one British airship, the latter making the flight in both directions.

Any scholar of German interested in aviation history will enjoy the pages of " Weltflieger "; even the less gifted will find the pictures of these early days capable of filling many of the gaps which the language barrier leaves.—JOHN GRIERSON.

PARTIAL DIFFERENTIAL EQUATIONS OF MATHEMATICAL PHYSICS. *A. G. Webster. Dover Publications, New York, 1955. 440 pp. $1.98.*

THE ANALYTICAL THEORY OF HEAT. *J. Fourier. Dover Publications, New York, 1955. 466 pp. $1.95.*

THE MATHEMATICAL ANALYSIS OF ELECTRICAL AND OPTICAL WAVE-MOTION. *H. Bateman. Dover Publications, New York, 1955. 159 pp. $1.60.*

Those readers who have occasion to use any of these standard text-books will be surprised to see an announcement of what appears to be three new editions, at a low price. There is no catch in the low price, but the 1955 publication date is that of the Dover reprint of an old edition. We have mentioned before the service that this publisher is doing in reproducing the old classic text-books that have been out of print for so long and librarians who have to form new libraries for an expanding industry, and university students who are feeding the insatiable maw of technology, have good reason to bless such enterprise.—F.H.S.

MODERN PETROL ENGINES. *Arthur W. Judge. Second Edition. Chapman and Hall. London, 1955. 564 pp. 339 diagrams and photographs. 56s.*

This is the second edition of a book first published in 1946 and described in a review in the Journal of April 1946 (p. 294) as " a very thorough study of the whole petrol engine field and one which should prove of great value to students and all those engaged in engine development." In the main the difference between this edition and the previous one is the addition of new chapters containing recent information relating to detonation research, combustion chamber design and alternative fuels for petrol engines.

Additions to the Library

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Blond, G. BORN TO FLY. Souvenir Press. 1956.

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Reports

AERODYNAMICS

Boundary Layer

The laminar boundary-layer with distributed suction on an infinite yawed cylinder. K. D. P. Sinha. C.P. 214. 1956. —(1.1.1).

Laminar flow about a rotating body of revolution in an axial airstream. H. Schlichting. N.A.C.A. T.M. 1415. (*February* 1956).

A method is given for calculating the incompressible laminar boundary layer on a rotating body of revolution at zero angle of attack in an air stream. The method is based on two boundary layer momentum equations, one for the meridional direction and one for the circumferential direction. A simultaneous solution of both momentum equations yields the boundary layer parameters, the friction drag, and the torque.—(1.1.1).

Cross flows in laminar incompressible boundary layers. A. G. Hansen and H. Z. Herzig. N.A.C.A. T.N. 3651. (*February* 1956).

An analysis is derived for the three-dimensional boundary layer flow over a flat surface with a leading edge under main flow stream lines which are translates and representable by polynomial expressions. The boundary layers are laminar and incompressible, and the profiles of their velocity components have similarity with respect to rectangular co-ordinates.—(1.1.1).

Some effects of bluntness on boundary-layer transition and heat transfer at supersonic speeds. W. E. Moeckel. N.A.C.A. T.N. 3653. (*March* 1956).

Large downstream movements of transition observed when the leading edges of a hollow cylinder or a flat plate are slightly blunted are explained in terms of the reduction in Reynolds number at the outer edge of the boundary layer due to the detached shock wave. This Reynolds number reduction leads to a predicted downstream movement of transition which is in good agreement with the hollow-cylinder result at Mach 3·1.—(1.1.2).

Effect of leading-edge geometry on boundary-layer transition at Mach 3·1. *P. F. Brinich. N.A.C.A. T.N.* 3659 (*March* 1956).

The effect of leading-edge geometry on transition, recovery factor, boundary layer profile, and the roughness required to induce transition was studied. A downstream displacement of transition and an increase in recovery factor with increasing leading-edge bluntness were found. These were associated with the formation of an inviscid shock-produced shear layer originating at the leading edge. Some effects of leading-edge blunting on roughness induced transition and the effect of surface heat conductivity on measured temperature distributions were also studied.—(1.1.2).

Compressible Flow

*The accuracy of the method of characteristics. M. G. Hall. A.R.L. Report A.*95 (*September* 1955).

The characteristics computation for two-dimensional supersonic flow is studied. The mechanism of error propagation is analysed. This is followed by a determination of the effects, on the results of the computation, of the various types of error introduced in its course. The theory can be used to plan computations in advance for achieving a specified accuracy with minimum labour.—(1.2.3).

Minimum-drag ducted and pointed bodies of revolution based on linearized supersonic theory. H. M. Parker. N.A.C.A. Report 1213. (1955).

The linearised drag integral for bodies of revolution at supersonic speeds is presented in a double-integral form which is not based on slender body approximations but which reduces to the usual slender body expression in the proper limit. With the aid of a suitably chosen auxiliary condition, the minimum external wave drag problem is solved for a transition section connecting two semi-infinite cylinders. The projectile tip is a special case and is compared with the von Kármán projectile tip.—(1.2.3).

Minimum wave drag for arbitrary arrangements of wings and bodies. R. T. Jones. N.A.C.A. T.N. 3530. (*February* 1956).

Studies of various arrangements of wings and bodies designed to provide favourable wave interference at supersonic speeds lead to the problem of determining the minimum possible value of the wave resistance obtainable by any disposition of the elements of an aircraft within given dimensions defined by a region. Under the assumptions that the total lift and the total volume of the aircraft are given, conditions that must be satisfied if the drag is to be a minimum are found. For arbitrary regions the minimum value can be estimated by a simple formula giving a lower bound.—(1.2.3).

Effect of transverse body force on channel flow with small heat addition. S. Ostrach and F. K. Moore. N.A.C.A. T.N. 3594 (*February* 1956).

As a channel flow traverses a plane normal to the flow axis over which heat sources are uniformly distributed, analysis shows the flow to be displaced in the direction of the body force, becoming a shear flow far downstream. If heat sources are distributed non-uniformly, vortices are produced by the action of the body forces. The cases of small Mach number and, separately, large Froude number are considered. The flow in a rotor-tip combustor of a helicopter ram-jet is considered as an example.—(1.2.3).

Bodies of revolution having minimum drag at high supersonic airspeeds. A. J. Eggers, et al. N.A.C.A. T.N. 3666 (*February* 1956).

Newtonian impact theory is used to determine body shapes of minimum drag under various combinations of the conditions of given body length, base diameter, surface area, and volume. In addition an estimate is made of centrifugal forces, and their effect on the minimum drag shapes is considered. An experimental investigation carried out in the Ames 10- by 14-inch supersonic wind tunnel on a family of bodies, including two of the minimum drag shapes, is found to provide a substantiation of the analysis.—(1.2.3).

Wing-body combinations with certain geometric restraints having low zero-lift wave drag at low supersonic Mach numbers. H. Lomax. N.A.C.A. T.N. 3667. (*February* 1956).

Several variational problems involving optimum wing and body combinations having minimum wave drags for different kinds of geometrical restraints are analysed. Particular attention is paid to the effect on the wave drag of shortening the fuselage and, for slender axially symmetric bodies, the effect of fixing the fuselage diameter at several points or even of fixing whole portions of its shape.—(1.2.3).

Internal Flow

On the permeability of porous materials. E. C. Yates, Jr. N.A.C.A. T.N. 3596. (*January* 1956).

The effects on porous material permeability characteristics of absolute pressure level (and associated scale effects), choking of the flow, bending the material, and other factors have been investigated. Samples of 30- by 250-mesh rolled Monel metal cloth and 1/16-inch thick sintered bronze were calibrated with constant upstream pressures of 1 atmosphere and 2½ atmospheres (varying downstream pressure) and with constant downstream pressure of 1 atmosphere (varying upstream pressure).—$1.5.0 \times 21.2.2$).

Stability and Control

Measurement of the derivative z_w for oscillating sweptback wings. G. E. Whitmarsh. C. of A. Report No. 92.

Measurements have been made of the derivative z_w for rigid swept-back wings mounted at zero incidence and oscillated with simple harmonic motion. The Reynolds number was in the range $1{\cdot}2 \times 10^5$ to $4{\cdot}1 \times 10^5$. The

NOTE.—*The figures in parenthesis at the end of each Summary are for ofice use only.*

wings were of trapezoidal plan form, chosen to indicate the effects of sweepback, aspect ratio and taper ratio. In each case the variation of z_w with frequency parameter was determined, and the effect of amplitude of oscillation checked, and found to be fairly small.—(1.8.2.2).

THERMO-AERODYNAMICS

Analysis of turbulent heat transfer, mass transfer, and friction in smooth tubes at high Prandtl and Schmidt numbers. R. G. Deissler. N.A.C.A. Report 1210 (1955).

The expression for eddy diffusivity from a previous analysis was modified in order to account for the effect of kinematic viscosity in reducing the turbulence in the region close to a wall. By using the modified expression, good agreement was obtained between predicted and experimental results for heat and mass transfer at Prandtl and Schmidt numbers between 0·5 and 3000. The effects of length-to-diameter ratio and of variable viscosity were also investigated for a wide range of Prandtl numbers.—(1.9.1).

WINGS AND AEROFOILS

Velocity calculations by conformal mapping for two-dimensional aerofoils. D. A. Spence and N. A. Routledge. C.P. 241. (1956).

A method is derived for computing the conformal transformation between the plane of an aerofoil of arbitrary shape (symmetrical or cambered), and the plane of its velocity potential at zero lift (in which the aerofoil contour becomes a slit), in order to permit calculations of the velocity at points off the surface. The integral equation which relates the contours is derived by an application of Cauchy's theorem, and solved to the order of the square of thickness ratio.—(1.10.1.1).

Wind-tunnel investigation at low speed of the effects of chordwise wing fences and horizontal-tail position on the static longitudinal stability characteristics of an airplane model with a 35° sweptback wing. M. J. Queijo, et al. N.A.C.A. Report 1203 (1954).

Low-speed tests of a model with a wing swept back 35° at the 0·33-chord line and a horizontal tail located well above the extended wing-chord plane indicated static longitudinal instability at moderate angles of attack for all configurations tested. The present investigation was made to determine whether the longitudinal stability could be improved by use of chordwise fences, by lowering the horizontal tail, or by a combination of both.—(1.10.2.2).

Flow studies on drooped-leading-edge delta wings at supersonic speed. W. H. Michael, Jr. N.A.C.A. T.N. 3614. (*January* 1956).

An experimental investigation of the flow over flat delta wings has been extended to include studies on delta wings with drooped leading edges. Vapour-screen, pressure-distribution, and ink-flow tests were made on a series of semi-span delta wings with semi-apex angles of 15°, 22.5°, and 31·75° and with 10 per cent. and 20 per cent. of the semi-spans drooped 15° in streamwise sections. The tests were made at a Mach number of 1·9.—(1.10.2.2).

TESTING AND INSTRUMENTS

A multi-tube manometer for an intermittent supersonic wind-tunnel. T. A. Thomson. A.R.L. Instruments Note 56. (*October* 1955).

Special features of a new manometer for the blow-down wind tunnel at the University of Sydney are described.—(1.12.1).

AEROELASTICITY

See also STRUCTURES—THEORY AND ANALYSIS

Tabulation of the f_λ functions which occur in the aerodynamic theory of oscillating wings in supersonic flow. V. Huckel. N.A.C.A. T.N. 3606. (*February* 1956).

The integrals which are denoted as the f_λ functions and which occur in the aerodynamic theory for wings oscillating in pure supersonic flow have been evaluated and tabulated for various Mach numbers and values of the reduced frequency. Specific values of parameters λ, M, and k for which tabulations of f_λ are presented are: $\lambda = 0$ to 11; Mach numbers of 1.2 to 5.0—(2.0).

AIRCRAFT OPERATION

Impingement of water droplets on a rectangular half body in a two-dimensional incompressible flow field. W. Lewis and R. J. Brun. N.A.C.A. T.N. 3658 (*February* 1956).

Trajectories of water droplets moving in the ideal two-dimensional flow field ahead of a body of rectangular cross section and infinite extent in the downstream direction have been calculated by means of a differential analyser. Data on collection efficiency and distribution of water impingement are presented.—(5).

FLIGHT TESTING

An investigation of high altitude cruising conditions for turbo-jet aircraft. R. T. Shields, et al. C.P. 215. (1956).

Specific air range has been measured on the Ashton Mk. 1 at high altitude using differing techniques. A "quasi-level" procedure consisting of runs at constant speed involving a small rate of climb or descent is recommended for performance measurements near the optimum range conditions and any speed below about $M = 1{\cdot}2$. Some evidence on scale effect on specific air range during a long range flight is shown. An Appendix derives and discusses the conditions for maximum specific air range, the argument being extended to the case with compressibility drag effects.—(13.3).

Methods for reducing seaplane take-off distances to standard conditions. J. A. Hamilton. C.P. 210. (1955).

Methods are developed for the reduction of seaplane take-off distances to standard conditions of weight, wind and ambient temperature. The expressions derived are applicable to the waterborne run and to the airborne run up to the 50 foot height point. The methods may be applied to take-off with simulated engine failure.—(13.1).

FUELS AND LUBRICANTS

Friction studies of graphite and mixtures of graphite with several metallic oxides and salts at temperatures to 1,000° *F. M. B. Peterson and R. L. Johnson. N.A.C.A. T.N.* 3657. (*February* 1956).

Powdered graphite was found to lubricate metal surfaces at temperatures in the vicinity of 1,000° F. when a metallic oxide film could be formed and maintained. Mixtures of soft metallic oxides such as lead oxide or cadmium oxide with graphite were effective lubricants at all temperatures from room temperature to 1,000° F. unless a chemical reaction occurred between the graphite and the oxide.—(14.3).

HYDRODYNAMICS

An experimental investigation of the scale relations for the impinging water spray generated by a planing surface. E. E. McBride. N.A.C.A. T.N. 3615. (*February* 1956).

An experimental investigation was made to determine the scale effects of the forces from water spray generated by a flat rectangular planing surface impinging on a collector plate representative of an aerodynamic surface or other part of a water-based aeroplane. Two models, one five times the linear dimensions of the other, were tested. The collector plate was located above, and aft of, the spray generator where spray could strike it. Lift and drag force coefficients for both the spray generator and spray collector are presented.—(17.2).

MATERIALS

See also RESEARCH

Blistering in aluminium alloys. I. J. Polmear and F. E. Beissel. A.R.L. Report Met. 14. (*October* 1955).

The occurrence of blisters on the surface of aluminium alloy components has, for many years, resulted in production losses due to the rejection of affected material. Although

the problem has been widely observed there is much which remains to be understood and a survey of all aspects of blister formation was considered desirable. Relevant information from the literature has been correlated with data supplied by various industries and research establishments in several countries.—(21.2.2).

Influence of temperature on creep, stress-rupture, and static properties of melamine-resin and silicone-resin glass-fabric laminates. W. N. Findley, et. al. N.A.C.A. T.N. 3414 (*January* 1956).

Results are reported of static tension, static compression, tension creep, and time-to-fracture tests of melamine-resin and silicone-resin glass-fabric laminates at temperatures up to 400° and 600° F., respectively.—(21.3.3).

The nickel dip: a radioisotope study of metallic deposits in porcelain enameling. J. C. Richmond, et al. N.A.C.A. T.N. 3577 (*February* 1956).

Radio-isotope tracer techniques were used to study the effect of the nickel dip on the deposition of cobalt metal during firing of a cobalt-bearing ground coat on pickled and sand-blasted iron, the effect of surface pretreatment on the amount and distribution of nickel deposited from the nickel dip on enamelling iron, and the effect of application and firing of cobalt-free and cobalt-bearing enamels on the chemical form and physical distribution of nickel previously deposited on enamelling iron by the nickel dip.—(21.3.1).

Wear of typical carbon-base sliding seal materials at temperatures to 700° F. R. L. Johnson, et al. N.A.C.A. T.N. 3595 (*February* 1956).

Wear and friction studies were made with carbon-type seal materials sliding against tool steel, stainless steel, and chromium-plated steel at temperatures to 700° F. and a sliding velocity of 10.000 feet per minute.—(21.2.1).

Influence of copper ions on adherence of vitreous coatings to stainless steel. D. G. Moore and A. G. Eubanks. N.A.C.A. T.N. 3679 (*February* 1956).

In another phase of an investigation of adherence of ceramic coatings to metals, the effect of copper oxide in promoting adherence of vitreous coatings to A.I.S.I. type 321 stainless steel was studied. The goal of this particular study was to determine whether the action of the copper ions was similar to that of cobalt ions in coatings for iron or whether the two actions were entirely different.—(21.3.1).

POWER PLANTS

A corrected speed tachosope. R. Staniforth. C.P. 224 (1956).

It is often desirable in testing aerodynamic compressors to take all readings at fixed corrected speeds rather than true speeds. This corrected speed is defined as the actual shaft speed divided by the square root of the ratio of the absolute air inlet temperature to the standard temperature (288° K.). With the instrument described, this is possible with high accuracy (error $< 0{\cdot}1$ per cent.) without further complication than the setting of a dial to the observed air inlet temperature.—(27.0).

The effect of lacing wire on axial compressor stage performance at low speeds. S. J. Andrews and H. Ogden. C.P. 225 (1956).

Four stages of Free Vortex blades were tested at low speed in the 106 compressor to determine the effects of lacing wire upon stage efficiency and temperature rise.—(27.1).

Turbinenschaufeln aus Kunststoff für Kaltluftuntersuchungen. K. Leist und W. Dettmering. DVL. Bericht Nr 4 (1955).

Die Verwendung von Kunststoffen verschiedener Art fur Stromungsmaschinenversuche empfiehlt sich insbesondere durch deren einfache Bearbeitbarkeit und hohe Reisslange bei tiefer Temperatur. Da Stromungsuntersuchungen vielfach mit Kaltluft durchgefuhrt werden, stellt die Verwendung derartiger Werkstoffe einen einfachen Weg zur schnellen Erzeugung verschiedener, auch komplizierter Schaulfelausfuhrungen dar. Der Bericht beschreibt das Herstellungsverfahren von ganzen Schaufelkranzen aus Plexiglas und einzelner Messchaufeln aus Giessharz sowie deren in Versuchen erprobte Anwendungsgrenzen.—(27.1).

Strömung vor einem Überschall-Laufrad. H. Söhngen. DVL. Bericht Nr. 11 (1955).

Untersucht wird die Stromung vor einem Uberschall-Axial-Verdichter, der nur aus einem Laufrad besteht und axial mit einer Unterschallgeschwindigkeit durchstromt wird. Insbesondere berucksichtigt werden dabei fur ein einfaches Modell die Reflexionen der von dem Laufrad ausgehenden Storungen an dem Einlauf und die dadurch bedingten Modifikationen der Stromung un die Schaufeln.—(27.1).

Theoretical and experimental investigation of mufflers with comments on engine-exhaust muffler design. D. D. Davis, Jr. et al. N.A.C.A. Report 1192 (1954).

Equations are presented for the attenuation characteristics of several types of mufflers. Experimental curves of attenuation plotted against frequency are presented for 77 different mufflers with reflection-free tail pipe terminations and for four different mufflers with finite tail pipes. The results are compared with theory. The experiments were made at room temperature without flow; the sound source was a loud-speaker.—(27.0).

Analog study of interacting and non-interacting multiple-loop control systems for turbojet engines. G. J. Pack and W. E. Phillips, Jr. N.A.C.A. Report 1212 (1955).

An analogue investigation of several turbo-jet control configurations was made. Both proportional and proportional-plus-integral controllers were studied, and compensating terms for engine inter-action were added to the control system. Data were taken on the stability limits and the transient responses of these various configurations. Analytical expressions in terms of the component transfer functions were developed for the configurations studied and the optimum form for the compensation terms was determined.—(27.1).

Cloud-droplet ingestion in engine inlets with inlet velocity ratios of 1·0 *and* 0·7. *R. J. Brun. N.A.C.A. T.N.* 3593 (*January* 1956).

The paths of cloud droplets into two engine inlets are calculated. The amount of water in droplet form ingested by the inlets and the amount and distribution of water impinging on the inlet walls are obtained from these droplet-trajectory calculations. In both types of inlet a prolate ellipsoid of revolution (10 per cent. thick) represents either part or all of the forebody at the centre of an annular inlet to an engine. The configurations can also represent a fuselage of an aeroplane with side ram-scoop inlets. The principal difference between the two inlets studied is that the inlet air velocity of one is 0·7 that of the other.—(27.1.1).

Summary of scale-model thrust-reverser investigation. J. H. Povolny et al. N.A.C.A. T.N. 3664 (*February* 1956).

Results of a scale-model thrust-reverser investigation are summarised. Three basic types of thrust reversers, target, tail pipe cascade, and ring cascade, were investigated. All three were found to have satisfactory reverse-thrust performance and thrust-modulation characteristics.—(27.1).

RESEARCH

La micrographie moyen de recherche quantitatif. H. Bückle and Cr. Bückle. O.N.E.R.A. N.T. 27 (1955).—(31.1 × 21.6).

Sur un nouvel analyseur analogique de régimes transitoires: application a l'etude de certains phénomènes de régime variable. J. Miroux. O.N.E.R.A. Publication No. 81 (1955). —(31.1 × 11.0).

Method and tables for determining the time response to a unit impulse from frequency-response data and for determining the Fourier transform of a function of time. C. R. Huss and J. J. Donegan. N.A.C.A. T.N. 3598 (*January* 1956).

Methods are presented for rapidly determining the time response to a unit impulse from frequency-response data and for obtaining the Fourier transform of a function of time. Tables are presented which facilitate the necessary computations of the methods.—(31.1 × 33.1.2).

SCIENCE — GENERAL

Structure asymptotique des ondes progressives comportant des fronts raides. J. Brillouin. O.N.E.R.A. Note Technique No. 30 (1956).—32.2.3).

Étude de la diffusion dans les gels a l'aide des isotopes radioactifs S. Cordier. Publications Scientifiques et Techniques, N.T. 57 (1956).—(32.2).

Acoustics of a nonhomogeneous moving medium. D. I. Blokhintsev. N.A.C.A. T.M. 1399 (*February* 1956).

Theoretical basis of the acoustics of a moving nonhomogeneous medium is considered. Experiments that illustrate or confirm some of the theoretical explanation or derivation of these acoustics are also included.—(32.2.3).

STRUCTURES

Loads

See also Research

The theory of torsional vibrations of a four-boom thin-walled cylinder of rectangular cross-section. E. H. Mansfield. R. & M. 2867 (1955).

The torsional vibrations of a four-boom cylinder of doubly symmetrical rectangular cross section are considered and the differential equation of motion is derived on the assumption that the ribs maintain the section shape, but do not themselves resist any warping out of their plane, and that the walls of the cylinder are effective only in shear. —(33.1.2).

A revised gust-load formula and a re-evaluation of V-G data taken on civil transport airplanes from 1933 *to* 1950. *K. G. Pratt and W. G. Walker. N.A.C.A. Report* 1206 (1954).

A revised gust-load formula with a new gust factor is derived to replace the gust-load formula and alleviation factor widely used in gust studies. The revised formula utilises the same principles and retains the same simple form of the original formula but provides a more appropriate and acceptable basis for gust-load calculations. The gust factor is calculated on the basis of a one-minus-cosine gust shape and is presented as a function of a mass ratio parameter in contrast to the ramp gust shape and wing loading, respectively used for the alleviation factor. A summary of gust-velocity data from V-G records taken on civil transport aeroplanes from 1933 to 1950, re-evaluated by the revised formula, is also presented. This report supersedes T.N. 2964 and T.N. 3041.—(33.1.1).

Statistical measurements of contact conditions of 478 *transport-airplane landings during routine daytime operations. N. S. Silsby. N.A.C.A. Report* 1214 (1955).

Statistical measurements have been obtained from photographs taken with a specially built motion-picture camera of 478 landings of present day transport aeroplanes during routine daylight operations in clear air at the Washington National Airport. From these measurements, sinking speeds, bank angles, rolling velocities, and horizontal speeds have been evaluated and a limited statistical analysis of the results has been made. An attempt was made to determine the effect of various parameters such as gusty-wind conditions, wing loading, and size of aeroplane (number of engines) which influence the landing contact conditions. (This Report supersedes T.N. 3194).—(33.1.2).

A method for obtaining statistical data on airplane vertical velocity at ground contact from measurements of center-of-gravity acceleration. R. C. Dreher. N.A.C.A. T.N. 3541 (*February* 1956).

A method is presented whereby the contact vertical velocities of aeroplanes are obtained on a statistical basis from measurements of maximum incremental centre-of-gravity acceleration. To evaluate this method, 268 landings have been made with a small trainer aeroplane. The vertical velocity probability curve based on the velocities obtained by this method is compared with the probability curve based on velocities obtained from a trailing arm velocity indicator. The agreement is very good. A limited amount of data for a medium bomber is presented; these data indicate that the method is probably applicable to large aeroplanes.—(33.1.2).

Comparison of landing-impact velocities of first and second wheel to contact from statistical measurements of transport airplane landings. E. N. Harrin. N.A.C.A. T.N. 3610 (*February* 1956).

A statistical analysis of vertical velocities at second wheel to touch was made from motion pictures of 353 landings of transport type aeroplanes at Washington National Airport. The effects of gusts, rolling direction, and number of engines are presented. Comparisons are made with vertical velocities of the first wheel to touch from N.A.C.A. T.N. 3194.—(33.1.2).

Gust-load and airspeed data from one type of two-engine airplane on six civil airline routes from 1947 *to* 1955. *W. G. Walker. N.A.C.A. T.N.* 3621 (*February* 1956).

V-G data covering 70,000 hours were obtained from six different operations of a two-engined civil transport aeroplane and are analysed to determine the severity and frequency of occurrence of the air speeds, gust loads, and gusts. The results show sizable variations in the gusts, gust loads, and operating speeds among the present operations but, in general, these results are similar to those from past operations of the same type of aeroplane.—(33.1.1).

Theory and Analysis

Pressure-cabin design; a discussion of some of the structural problems involved, with suggestions for their solution. D. Williams. C.P. 226 (1956).

The problems that arise in the design of a pressure cabin are almost entirely due to the numerous structural discontinuities that inevitably break up the otherwise smooth distribution of stress. Some of the main discontinuities, such as are caused by windows, doors, canopies, floors, formers, bulkheads and domes, are discussed here, and design suggestions are made for dealing with them.—(33.2.3.3).

Correlated fatigue data for aircraft structural joints. R. B. Heywood, C.P. 227 (1955).

Results of fatigue tests carried out at R.A.E. on typical aircraft wing structural joints are correlated to give an indication of general fatigue behaviour. The results are plotted in the form of *S*—Log *N* curves, and these indicate that the mode of behaviour cannot be attributed to any single factor, such as the type of aluminium alloy, the ultimate tensile strength, or the mean stress of the fatigue cycle. The detailed method of design undoubtedly has a predominant influence on behaviour, but this quality is not revealed by a broad classification according to the proportion of load transmitted at holes.—(33.2.4.13.10).

Neutral holes in plane sheet reinforced holes which are elastically equivalent to the uncut sheet. E. H. Mansfield. R. & M. No. 2815 (1955).

It is shown that, in a plane sheet under any particular loading system, certain reinforced holes may be made which do not alter the stress distribution in the main body of the sheet. These reinforced holes (hereafter called neutral holes) necessarily have exactly the same stiffness and at least the same strength as the portion of the sheet that has been cut out. The weight of the reinforcement is usually greater than the weight of the sheet that has been cut out, though there are cases where it is less.—(33.2.4.6.1).

The influence of the torsion-bending constant on the lateral instability of beams in the elastic range. J. Solvel. A.R.L. Report S.M. 231 (*August* 1955).

The influence of the torsion-bending constant on the lateral instability of beams having uniform cross sections is investigated using approximations based on strain energy method. The results are given in the form of ratios of critical loads causing lateral buckling, based on finite values of the torsion-bending constant, to those neglecting the latter, which are already well known. As the critical loads neglecting the torsion-bending constant are well known, inclusion of that constant can be done by using the above-mentioned ratios. All the results refer to beams of constant cross section only.—33.2.4.1.6).

Stress concentrations at the corners of a trapezoidal plate. L. H. Mitchell. A.R.L. Report S.M. 232 (*September* 1955).

In an endeavour to discover why agreement between theory

and experiment is not good, the stresses in a strip with constant edge strains and a free end at 45 degrees have been found by relaxation. The results are compared with the photo-elastic experiments of Coiley.—(33.2.4.7.3).

Formulas for the elastic constants of plates with integral waffle-like stiffening. N. F. Dow et. al. N.A.C.A. Report 1195 (1954).

Formulae are derived for the elastic constants of plates with integral ribbing. The constants, which include the effectiveness of the ribs for resisting deformations other than bending and stretching in their longitudinal directions, are defined in terms of four coefficients, and methods for the evaluation of these coefficients are discussed. Four of the more important elastic constants are predicted by these formulae and are compared with test results. (This Report was formerly R.M.L.53113a).—(33.4.6.0).

Charts relating the compressive buckling stress of longitudinally supported plates to the effective deflectional and rotational stiffness of the supports. R. A. Anderson and J. W. Semonian. N.A.C.A. Report 1202 (1954).

The stability of a plate under edge compressive stress is analysed in terms of the deflectional and rotational stiffness of one or more longitudinal lines of support between the plate side edges. The results are presented in the form of charts which make possible the determination of the compressive buckling stress of plates, supported by members whose stiffness may or may not be defined by elementary beam bending and twisting theory, yet whose effective restraint is amenable to evaluation. The deflection and rotational restraint provided by longitudinal stiffeners and full depth webs is discussed, and numerical examples illustrate the application of the charts to the design of wing structures. (This Report supersedes T.N. 2987).—(33.2.4.6.6).

Interim report on fatigue characteristics of a typical metal wing. J. L. Kepert and A. O. Payne. N.A.C.A. T.M. 1397 (*March* 1956).

Constant amplitude fatigue tests of seventy-two P-51D "Mustang" wings are reported. The tests were performed by a vibrational loading system and by an hydraulic loading device for conditions with and without varying amounts of pre-load.—(33.2.3.1.10).

Investigation of the compressive strength and creep lifetime of 2024-*T3 aluminium-alloy plates at elevated temperatures. E. E. Mathauser and W. D. Deveikis. N.A.C.A. T.N.* 3552 (*January* 1956).

The results of elevated temperature compressive-strength and creep tests of 2024-T3 (formerly 24S-T3) aluminium-alloy plates supported in V-grooves are presented. The strength test results indicate that a relation previously developed for predicting plate compressive strength at room temperature is satisfactory for determining elevated temperature strength.—(33.2.4.5.9 × 33.2.4.5.6).

Compressive crippling of structural sections. M. S. Anderson. N.A.C.A. T.N. 3553 (*January* 1956).

A method is presented for calculating crippling stresses of structural sections as a function of material properties and the proportions of the section. The presence of formed or anisotropic material is accounted for by the use of an effective stress-strain curve. The method of analysis applies to many sections for which a procedure for calculating crippling was not previously available.—(33.2.4.2.6).

Correlation of crippling strength of plate structures with material properties. R. A. Anderson and M. S. Anderson. N.A.C.A. T.N. 3600 (*January* 1956).

A correlation approach to the crippling-strength analysis of multiplate-element structures in new materials and at elevated temperatures is presented. Appropriately defined crippling-strength moduli and correlation procedures are given for predicting the effect of a change in material properties on the strength of a structure. The accuracy of the approach is illustrated with available experimental data obtained in various materials and under different temperature conditions.—(33.2.4.6.6).

Experimental investigation of the vibrations of a built-up rectangular box beam. E. E. Kordes and E. T. Kruszewski. N.A.C.A. T.N. 3618 (*February* 1956).

Experimental modes and frequencies of a uniform built-up box beam are presented and comparisons are made between experimental and theoretical frequencies.—(33.2.4.1.10 × 2).

STRUCTURES

Testing

An electronic apparatus for accurate measurement of periodic strains. G. V. A. Gustafsson and C. O. Olsson. F.F.A. Report 63 (1956).

An electronic apparatus is described which will measure accurately the static value as well as the extreme values of a periodically varying phenomenon. It is especially adapted for measuring strains and loads in fatigue testing.—(33.3.1).

THERMODYNAMICS

Optimum design of a vortex tube for achieving large temperature drop ratios. R. Westley. C. of A. Note 30.

The vortex tube, invented by G. J. Ranque, is a simple device which separates a flow of compressed gas into a hot and a cold stream by means of a high speed vortex. It may have useful applications as a refrigerator and one of the aims of the present investigation was to widen the field of application by increasing the vortex tube's cooling performance. The described tests determined the effect of the hot valve setting, the cold outlet diameter, the inlet nozzle size and the inlet pressure ratios, upon the temperature drop ratio characteristics of a vortex tube.—(34).

Generalized tables of corrections to thermodynamic properties for nonpolar gases. H. W. Woolley and W. S. Benedict. N.A.C.A. T.N. 3272 (*March* 1956).

Tables are presented based on the Lennard-Jones 6-12 potential for non-polar molecules for use in representation of second and third virial coefficients and equation of state corrections for enthalphy, entropy, specific heats at constant pressure and volume, specific heat ratio, isentropic expansion coefficient, and sound velocity. The treatment for effects involving three molecules jointly uses an empirical adjustment of the Lennard-Jones parameters within a cluster of three independently of the value for an isolated pair. A graphical correlation of ratios of these parameters with the critical constants is also shown.—(34.1).

Heat capacity lag of gaseous mixtures. T. D. Rossing, et. al. N.A.C.A. T.N. 3558 (*March* 1956).

A study was made of the vibrational energy lag in heavy organic gases. Results of measurements of sonic dispersion made with an acoustic interferometer in a number of heavy bases are presented and certain fundamental properties of the vibrational excitation process in these gases are discussed.—(34.1).

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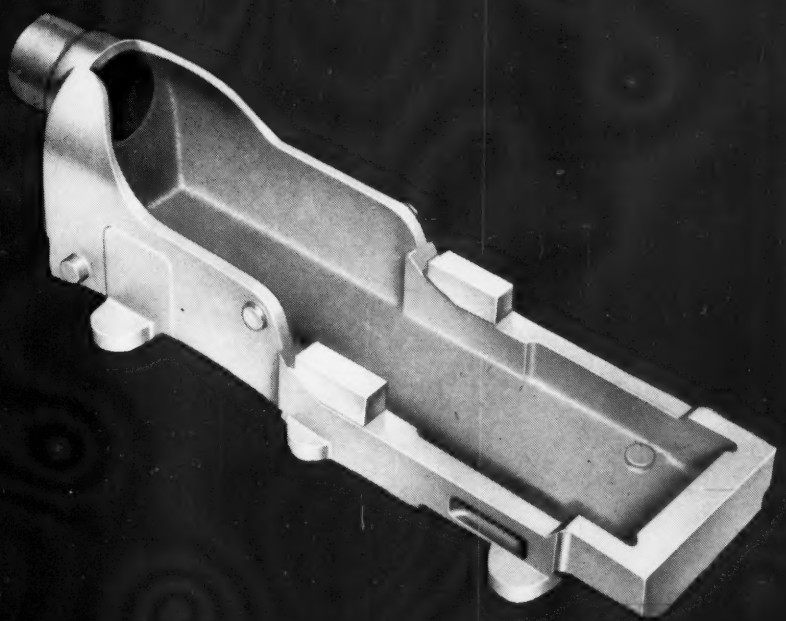

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